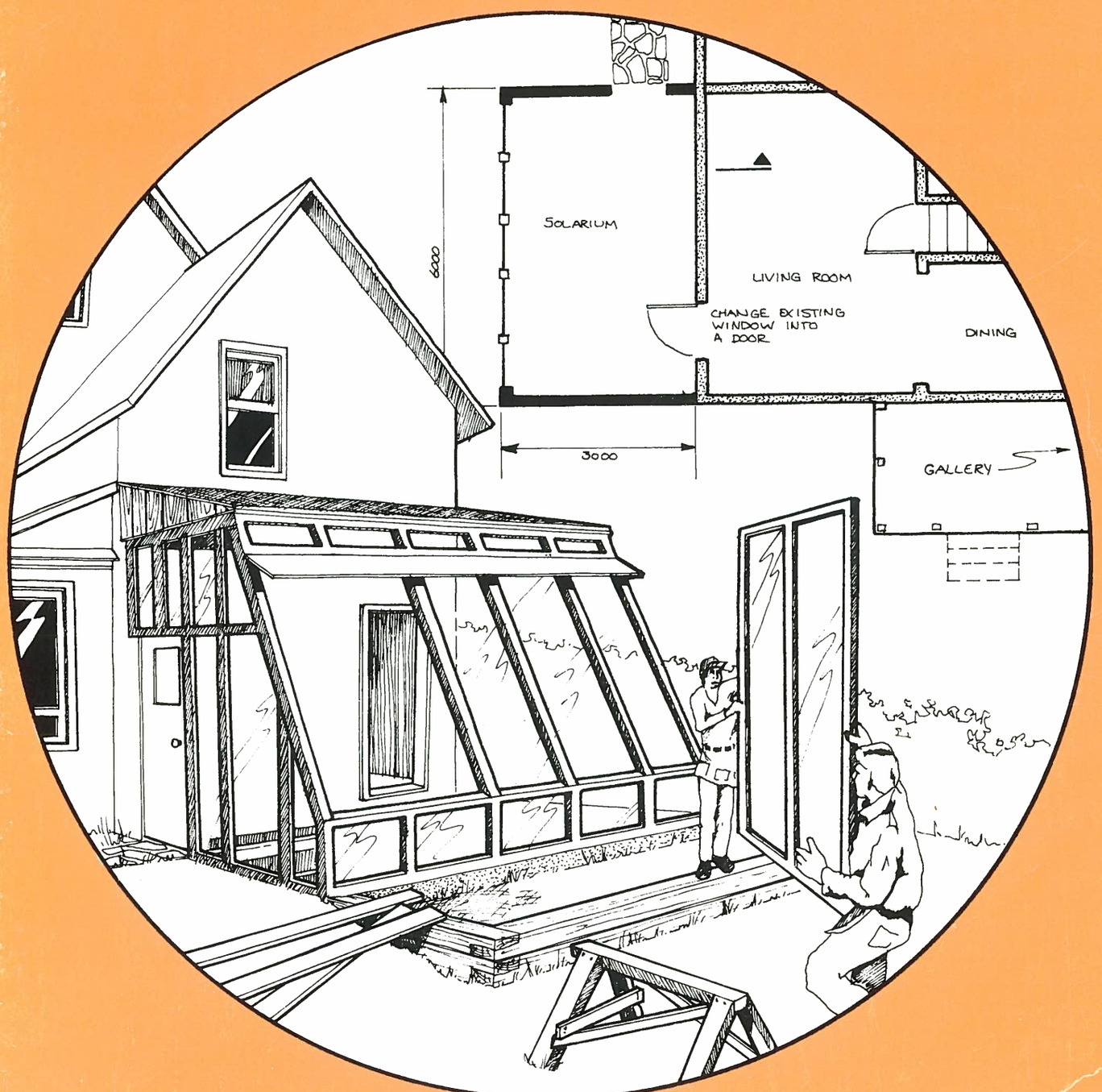
The SOLARIUM WORKBOOK



SOLARIUM WORKBOOK

Addenda and Errata

P. 2 (middle of page) - On a horizontal surface the annual insolation averaged over day and night, winter and summer, is about 150W/m^2.

P. 45 (margin) - gf = 9.44 ÷ 10.80 = 0.87

P. 47 - (for the explanation of Col.1). You should use the orientation which is closest to your own particular case. Should your orientation or inclination fall between those listed, a simple interpolation between values is appropriate.

P. 47 - New solar radiation tables for inclined surfaces are now available for many more cities across Canada from:

Atmospheric Environment Service,
4905 Dufferin St.,
Downsview, Ontario,
M3H 5T4.

These tables are in MJ/[m^2.d]. To convert to the same units (W.h/[m^2.d]) as used in this book simply multiply by 1000 and divide by 3.6.

P. 50 - UA1 expressed in kW/°C is $\frac{83.94}{1000} \simeq 0.084$

P. 51 - The operating daytime temperature of the solarium must be somewhat higher than that of the house if heat is to be transferred to the house. A reasonable value for t_i to calculate the heat losses for the day would be about the house temperature + 5°C, e.g. if the house is at 20°C, then t_i would be 25°C. During very sunny days even with the fans working the temperature of the solarium given in the example could climb to 30°C.

P. 99 (top of page) - This can produce a flow of air.

The SOLARIUM WORKBOOK

National Research Council of Canada

Solar Technical Series No. 2

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May, 1981

FOREWORD:

Although solaria have been with us for many years, the concern for energy-efficient designs suitable for the Canadian climate has only recently come to the fore. It gives me pleasure to acknowledge the pioneering effort of Hawes and Wight Ltd. and the Brace Research Institute for amassing much of the material needed to produce this workbook.

It can be expected that considerable progress will be made in the near future, both with respect to more refined thermal performance evaluation techniques and new construction methods (e.g. efficient thermal shutters). Nevertheless, I am confident that the broad base of information made accessible in this publication now represents a very useful guide to the homeowner seriously considering the addition of a solarium to his house.

To all the eventual energy-conscious builders, I wish success.

The Scientific Authority for Publication.

This publication is based on a study carried out for the Solar Energy Project of the National Research Council under Contract No. OSX78-00100 between February 1979 and October 1979. This study was entitled:

A Solarium Design Guide for Canadian Homes

The scientific authority for this original study was Mr. K.G. Lund of the Solar Energy Project.

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CHAPTER 1
INTRODUCTION

In Canada, solaria have been built onto large houses for many years, such as this one in Outremont, Quebec.

Heating systems using solar energy have been architectural features in buildings for hundreds of years. Solaria or atria, as they are called, have ranged in size from huge structures like the Crystal Palace and the Palm House built in England during the 1800's to small bay windows found in houses throughout the centuries.

The two most important functions of these solaria were the collection of solar energy and the provision of a space that was visually open to the environment but protected from the elements. These structures were predominantly domestic and usually reserved for some horticultural function.

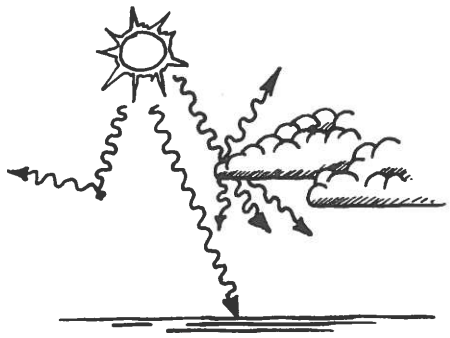
After World War II, architects became interested in using extensive amounts of glass to allow in light and create a feeling of spaciousness in their buildings. However, most of these buildings were prodigious wasters of fuel; not only was the collected solar energy wasted, but additional energy was required for its removal through air conditioning.

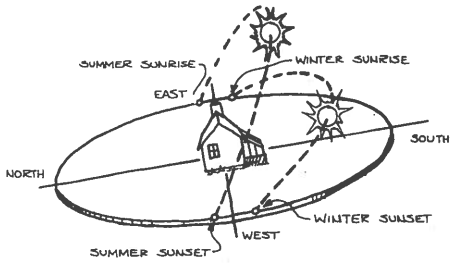
While such spaces were once constructed mainly for pleasure, they can be designed to provide some of the space heating of the house. This combination of an enjoyable living space and the practical heating potential should make a solarium an attractive investment for many people.

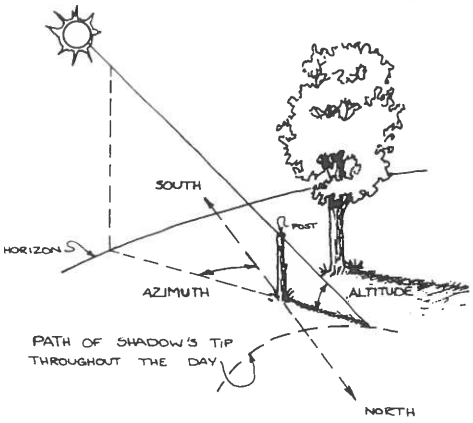
The goal of this workbook is to provide you with most of the necessary information to enable you to design and construct an energy-efficient solarium. This information is extensive, and so it may take some effort on your part to assimilate it. The task will be easier if you remember one thing: you will reap the rewards of the effort put into the energy-efficient approach for years to come.

A quick review of the table of contents will show you that a step-by-step approach as been adopted to guide you through the various stages of solarium design and construction, from an explanation of basic terms and concepts to energy and economic calculations, to details of the construction work and contracting procedures. Your particular skills or interests may make certain sections less important to you. The division of the different subjects was arranged to allow you to concentrate on those aspects most pertinent to your particular needs.

The horticultural use of a solarium as a greenhouse is not dealt with in this book except in explaining the influence this use may have on its design and operation. If your prime interest is in a greenhouse you would be wise to supplement this guide with reading material on plant cultivation and greenhouse management. Some of the publications on this subject are listed in the bibliography.







Some Metric Conversions

1 kilowatt (kW) = 1 000 watts (W)
1 joule (J) = 1 watt · second (W · s)
1 kilowatt hour (kW · h) =
3 600 kilojoules (kJ)
1 metre = 39.36 inches

Definitions, Terms and Concepts

Solar Energy

The sun transmits energy to the earth in the form of electromagnetic radiation which travels in a straight line from the sun to the earth's atmosphere. Some of this radiation impinging upon the atmosphere is transmitted directly to the earth's surface, some is reflected away, and another portion is scattered in all directions to become diffuse radiation.

Under ideal conditions the intensity of radiation can be as high as 1 kW/m^2 for an area perpendicular to that radiation. This level of intensity is not consistently achieved for a few obvious reasons:

1) Meteorological conditions, e.g. greater cloud cover means fewer hours of sunshine in Vancouver than in Victoria.
2) The maximum of 1 kW/m^2 could only be achieved by a system tracking the sun's position. Any surface not perpendicular to the sun's rays receives less radiation. The fraction by which it is decreased is equal to the cosine of the angle between the solar radiation and the perpendicular to the collector surface. On a horizontal surface the annual insolation averaged over day and night, winter and summer, is about 150 kWh/m^2 for inhabited regions of Canada. This amounts to 1 300 kWh/m^2 for a year. To put this in perspective, the annual heating demand for an average house in Ottawa is some 35 000 kWh.

The **position of the sun** in relation to a site at any place on earth at anytime may be described by two angles: the azimuth and the altitude.

Azimuth is the horizontal angle of the sun east or west of true south at anytime of day.

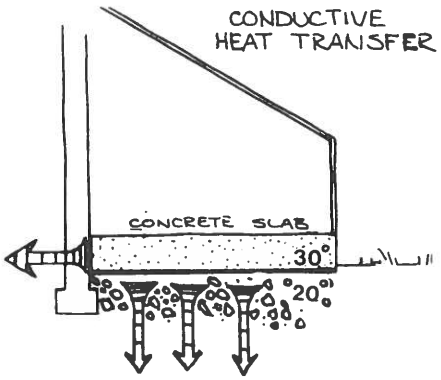
Altitude is the vertical angle of the sun above the horizon.

The sun's path in the sky varies with the time of year and latitude. It is low on the horizon in winter and rises to a higher position in summer. The point on the horizon where the sun rises and sets relative to any site also changes from summer to winter.

Thermal Energy Transfer

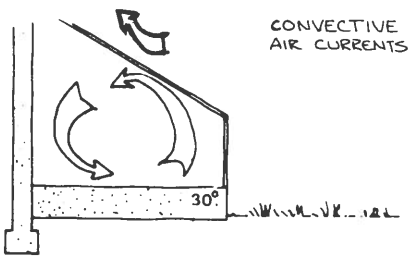
Solar radiation can be converted into thermal energy—heat—when the radiation is absorbed by a substance. This heat energy can be transferred in three basic ways: conduction, convection, and radiation.

Conduction is the heat flow from a region of higher temperature to a region of lower temperature within a solid, liquid, or gaseous medium, or between different media in direct physical contact. For instance, a sunlit concrete slab will transmit heat by conduction to all materials in contact with it. The rate at which it conducts this heat will depend upon the area of contact, the temperature difference between the materials, and the **thermal resistance** of the materials. The thermal resistance has been expressed as an R value for insulating materials but, with the conversion to metric, it is now expressed as an RSI value, where an R value of 1 is equivalent to an RSI value of 0.1761 $m^2 \cdot °C/W$. The higher the RSI value, the higher the thermal resistance.



Convection is the heat flow by currents induced by buoyancy forces within a fluid.

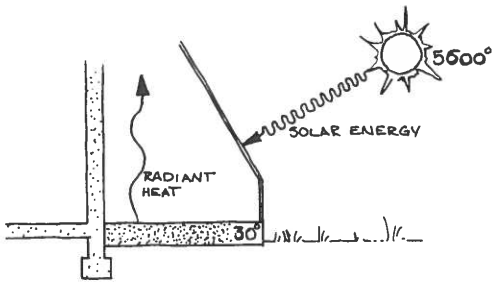
The transfer of heat by convection from a warm surface to a cooler fluid takes place in several steps. First, heat flows by conduction from the warm surface to the adjacent fluid. This warmed fluid is now lighter and tends to rise, with cooler fluid flowing down to take its place. As the fluid currents are set up mixing takes place which tends to distribute the heat more evenly.



Much of the heat of the sunlit concrete slab is transferred to the air in the solarium by convection.

Radiation is the heat flow from a high-temperature body to one at a lower temperature when the bodies are not in contact, even when a vacuum exists between them.

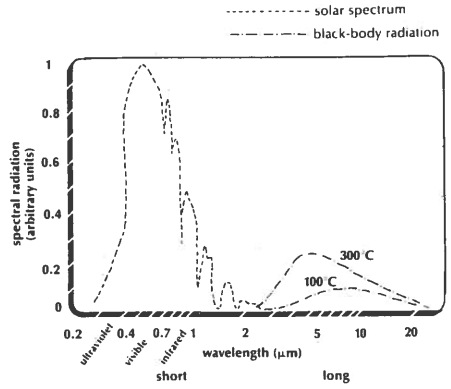
The rate at which heat is radiated is strongly dependent on the temperature. As the temperature rises, the radiation emitted increases. The temperature also determines the wavelengths over which radiation occurs. For instance, the sun is at a very high temperature and emits a significant portion of its energy at the short wavelengths typical of visible light. The solarium is at a much lower temperature and emits longer wavelengths which are sensed, not as light, but as radiant heat, like that from a wood stove.



Emissivity is the ability of a body to radiate heat as compared to that of a perfectly black body radiating at the same temperature. A black stove has a much higher emissivity than a shiny aluminum one and thus radiates more heat at the same temperature.

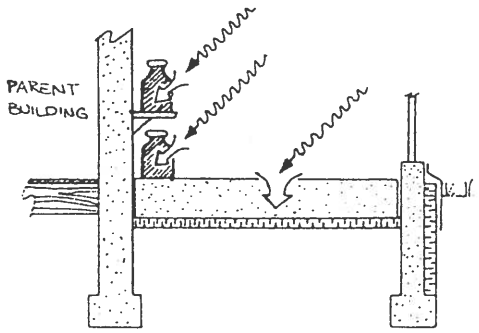
Absorptivity is the ability of a surface to absorb radiation which strikes it. The absorptivity of a surface varies with different wavelengths of radiation. The amount of energy absorbed at any given wavelength also depends on the angle of incidence of the radiation—the greater the angle of incidence, the lower the absorption.

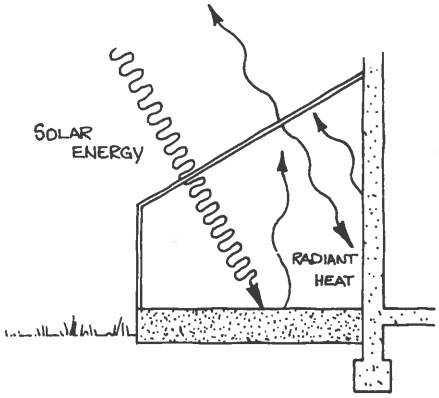
Reflectivity is the ability of a surface to reflect radiation. The reflectivity of a surface usually varies with different wavelengths of radiation. The reflectivity also varies with the angle of incidence of the radiation—the greater the incidence, the greater the reflectivity.



Thermal Mass

The energy needed to raise by one degree the temperature of a certain volume varies widely from one substance to another. The measure of the energy needed is referred to as the thermal mass; or explicitly, the energy needed to raise one unit of volume one degree in temperature is referred to as the volumetric heat capacity. For instance, concrete has a heat capacity of about 2 000 $kJ/(m^3 \cdot °C)$, water, 4 186 $kJ/(m^3 \cdot °C)$, and air, 1.2 $kJ/(m^3 \cdot °C)$. Water is thus a very good medium for the storage of thermal energy, while air is very poor.





The Greenhouse Effect

The greenhouse effect refers to the partial trapping of the solar energy as it is absorbed within a glazed enclosure. The glazing transmits a large portion of the incident short-wave solar radiation while it poses a greater barrier to the energy which tends to be transferred from the interior to the exterior. The glazing inhibits direct convective flow to the exterior and is usually far less transparent to the long-wave radiation emitted from the interior surfaces than to the short-wave solar radiation.

This greenhouse effect is the basis for the use of a solarium as a heat supplier to the house.

The Energy Efficient Solarium

The basic requirements for an energy efficient solarium are:

1) Proper inclination of glazing for maximum energy per unit area and for low reflection of incident radiation during the heating season. For Canadian latitudes this means that high inclinations (60°) are preferable to low inclinations (30°).

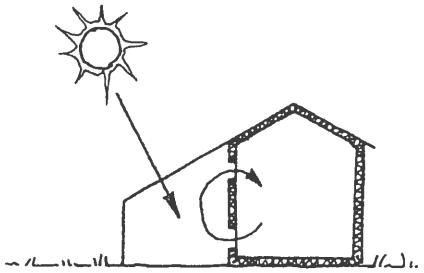
2) Proper glazing material for high short-wave transmission with low long-wave transmission.

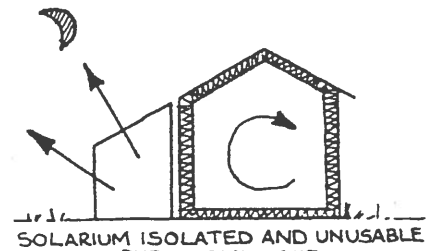
   Glass transmits short-wave (optical) radiation but absorbs long-wave radiation. It would be preferable if the glazing reflected long-wave radiation. Such reflective infrared coatings are being studied at this time.

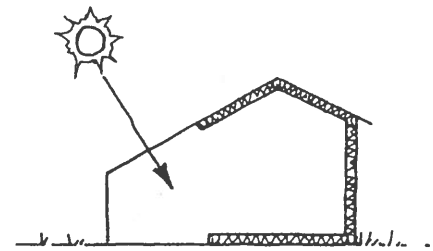
   Some plastic materials like polyethylene actually transmit the long-wave radiation well and are therefore less efficient in trapping the energy within the solarium.

3) Low heat losses. Even though a single glazing partially traps heat, it is a relatively poor insulator, having an RSI value of 0.15, which is some 12 to 20 times less than a typical fibreglass-insulated wall. It is relatively simple to have high light transmission as with a glass window, or to have high insulation as with a fibreglass-insulated wall, but it is difficult to combine these two desired characteristics.

   Thus, a solarium will have the tendency of being a source of heat during the day, but an important heat loser at night, especially if one tries to maintain moderate temperatures in it. This suggests some very different approaches to the design of a solarium.


SOLAR COLLECTOR BY DAY


SOLARIUM ISOLATED AND UNUSABLE DURING THE NIGHT


SOLAR COLLECTOR AND USABLE ROOM DURING THE DAY

Types of Solaria

Type 1 is a daytime heat supplier to the parent building. Night losses are inconsequential as temperatures are allowed to drop to low levels. This limits the solarium to occasional use as a living space. Thermal mass should not be present so that maximum heat can be transferred to the house. Nothing inside the solarium should be subject to damage by freezing as close to outside temperatures will prevail at night.

Type 2 is an additional heated space where a certain minimum temperature must be respected, e.g. for a greenhouse. This will probably not be cost-effective as a heat supplier because of the cost of the more elaborate insulation system of movable shutters, or the alternative additional expense of night heating. Thermal mass should be present to moderate variations in temperature from day to night.

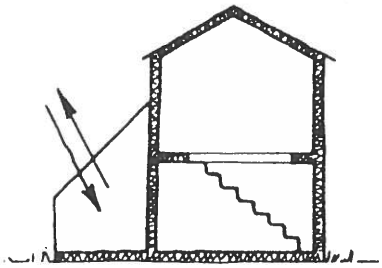
Type 3 is the same as Type 1 but with auxiliary heating to make it suitable as a living space when desired.

Distribution of the Collected Solar Heat to the Parent Building

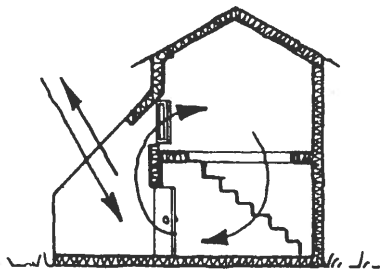
There are three ways of transferring heat from the solarium to the parent building.

1) Conduction through the common wall to the parent building. For this to be effective the wall should directly absorb the solar energy and transmit it with low resistance toward the principal building. A concrete or stone wall would work well but not a wood-frame construction. The added thermal mass would be appropriate for a type 2 design. However, the low thermal resistance desirable in the day for type 1 and 3 solaria would be much less so at night when insulation from the main building is important. Then one would have to provide movable thermal insulating panels or shutters between the building and the solarium for nighttime use.
2) Passive ventilation. The warm air is distributed from the solarium to the adjacent rooms in the parent building by natural convection through openings in the common wall.
3) Active ventilation. Air is forced to circulate from the solarium to the house by mechanical devices such as fans. Ventilation will probably be required in order to prevent overheating in summer.

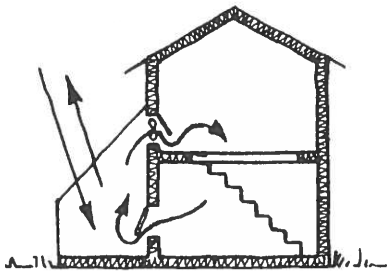
   If the solarium is used as a greenhouse the warm air conveyed to the parent building will be very humid. If the building has a problem of dryness in winter, this humidity may be desirable. But, for a new house with a low air infiltration rate it may cause problems.



NO DIRECT EXCHANGE OF AIR



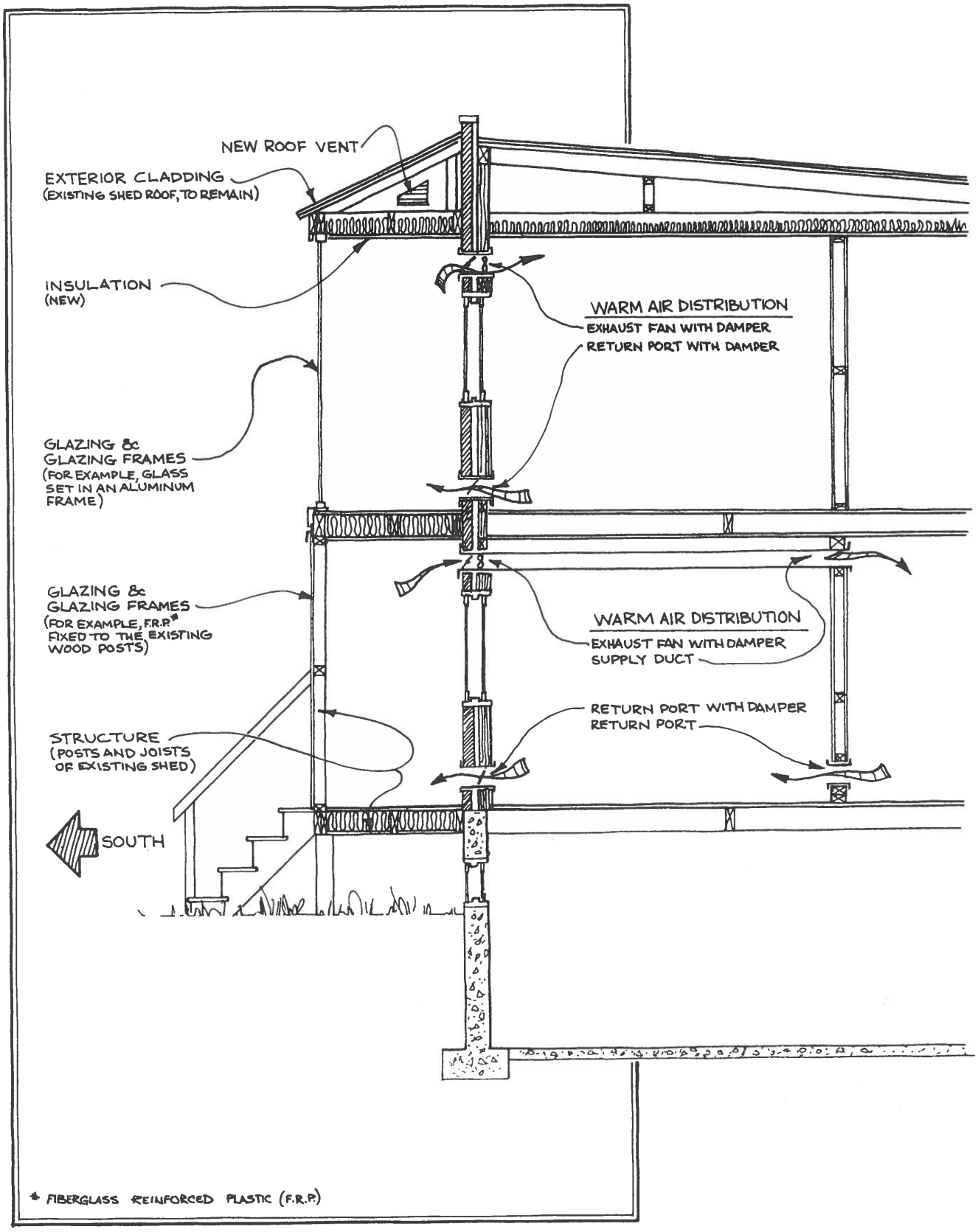
PASSIVE DISTRIBUTION



ACTIVE DISTRIBUTION

Solarium Design Possibilities

The following are descriptions of six different examples of solaria. Since certain features discussed in one example may be common with another, it is wise to examine each one carefully even though it may not represent your own specific case. A study of these solaria should provide you with some ideas to incorporate into your own design.


NEW ROOF VENT
EXTERIOR CLADDING
(EXISTING SHED ROOF, TO REMAIN)
INSULATION
(NEW)
WARM AIR DISTRIBUTION
EXHAUST FAN WITH DAMPER
RETURN PORT WITH DAMPER
GLAZING &
GLAZING FRAMES
(FOR EXAMPLE, GLASS
SET IN AN ALUMINUM
FRAME)
GLAZING &
GLAZING FRAMES
(FOR EXAMPLE, F.R.P.*
FIXED TO THE EXISTING
WOOD POSTS)
WARM AIR DISTRIBUTION
EXHAUST FAN WITH DAMPER
SUPPLY DUCT
RETURN PORT WITH DAMPER
RETURN PORT
STRUCTURE
(POSTS AND JOISTS
OF EXISTING SHED)
SOUTH
* FIBERGLASS REINFORCED PLASTIC (F.R.P.)

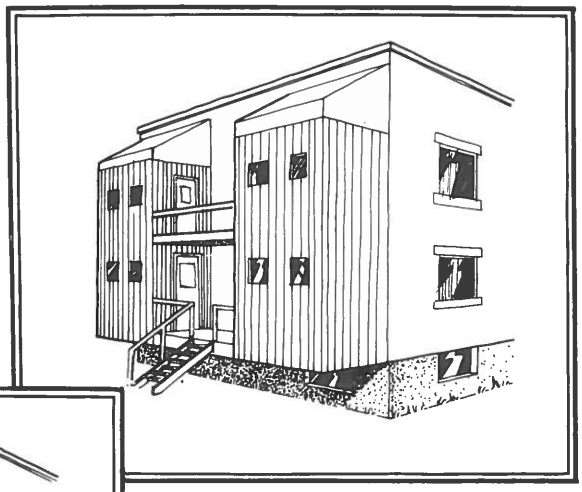
1. Conversion of a Balcony Storage Shed

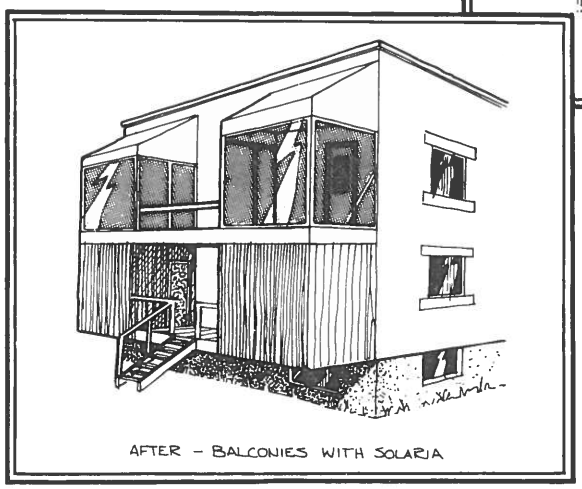
Solarium Type: Heat Supplier
Air Distribution: Active Ventilation
Thermal Mass: No

Some balcony storage sheds can easily be converted into solaria by simply replacing the opaque walls with a glazing material and providing some insulation in the non-glazed areas. Converting an existing shed has the advantage of avoiding the cost of a new foundation and structure.

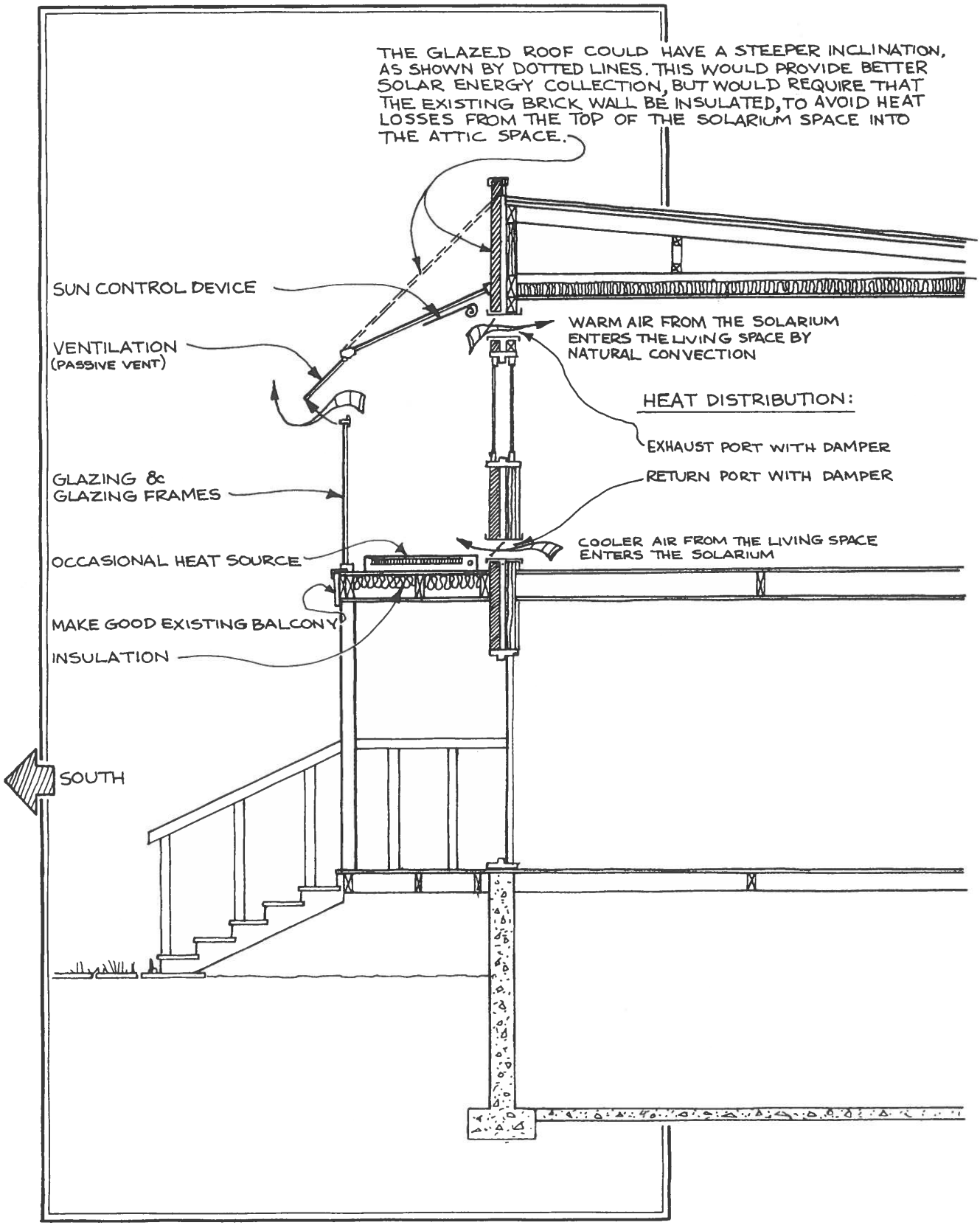
While some glazings can easily be attached to the wood frame which supported the original wood siding, others require special support systems. These may be expensive and may require removal of part of the existing structure.

An exhaust fan and return port with control dampers exchanges air between the solarium and living space. Warm air can also be distributed to living spaces, not adjacent to the solarium, by ductwork. For this, additional return ports may be necessary in interior partitions, but often hallways will serve as a natural air route.





Solarium Design Example 1


THE GLAZED ROOF COULD HAVE A STEEPER INCLINATION, AS SHOWN BY DOTTED LINES. THIS WOULD PROVIDE BETTER SOLAR ENERGY COLLECTION, BUT WOULD REQUIRE THAT THE EXISTING BRICK WALL BE INSULATED, TO AVOID HEAT LOSSES FROM THE TOP OF THE SOLARIUM SPACE INTO THE ATTIC SPACE.
SUN CONTROL DEVICE
VENTILATION (PASSIVE VENT)
GLAZING & GLAZING FRAMES
OCCASIONAL HEAT SOURCE
MAKE GOOD EXISTING BALCONY
INSULATION
SOUTH
WARM AIR FROM THE SOLARIUM ENTERS THE LIVING SPACE BY NATURAL CONVECTION
HEAT DISTRIBUTION:
EXHAUST PORT WITH DAMPER
RETURN PORT WITH DAMPER
COOLER AIR FROM THE LIVING SPACE ENTERS THE SOLARIUM

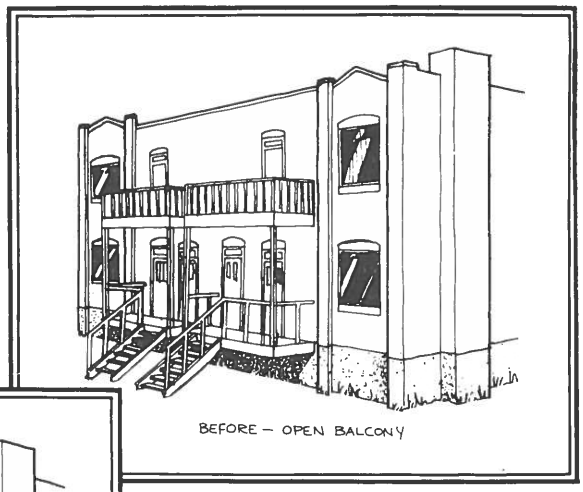
2. Solarium on a South-Facing Balcony

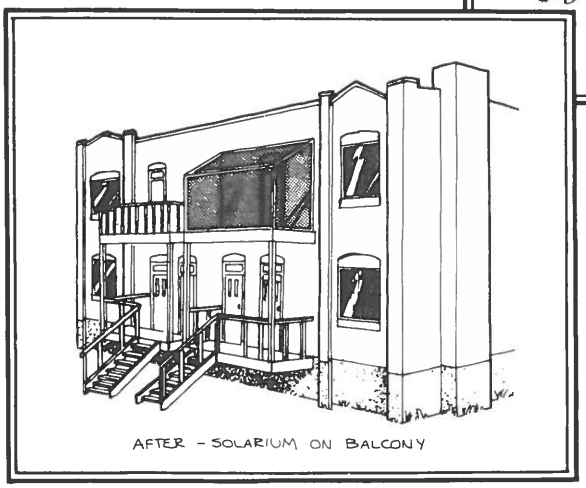
Solarium Type: Occasional Heated Space
Air Distribution: Passive Ventilation
Thermal Mass: No

In converting a balcony to a solarium, you must first ensure the structure can support the weight of the solarium and its contents, and that the balcony can be insulated. Again, using the existing structure can save you money.

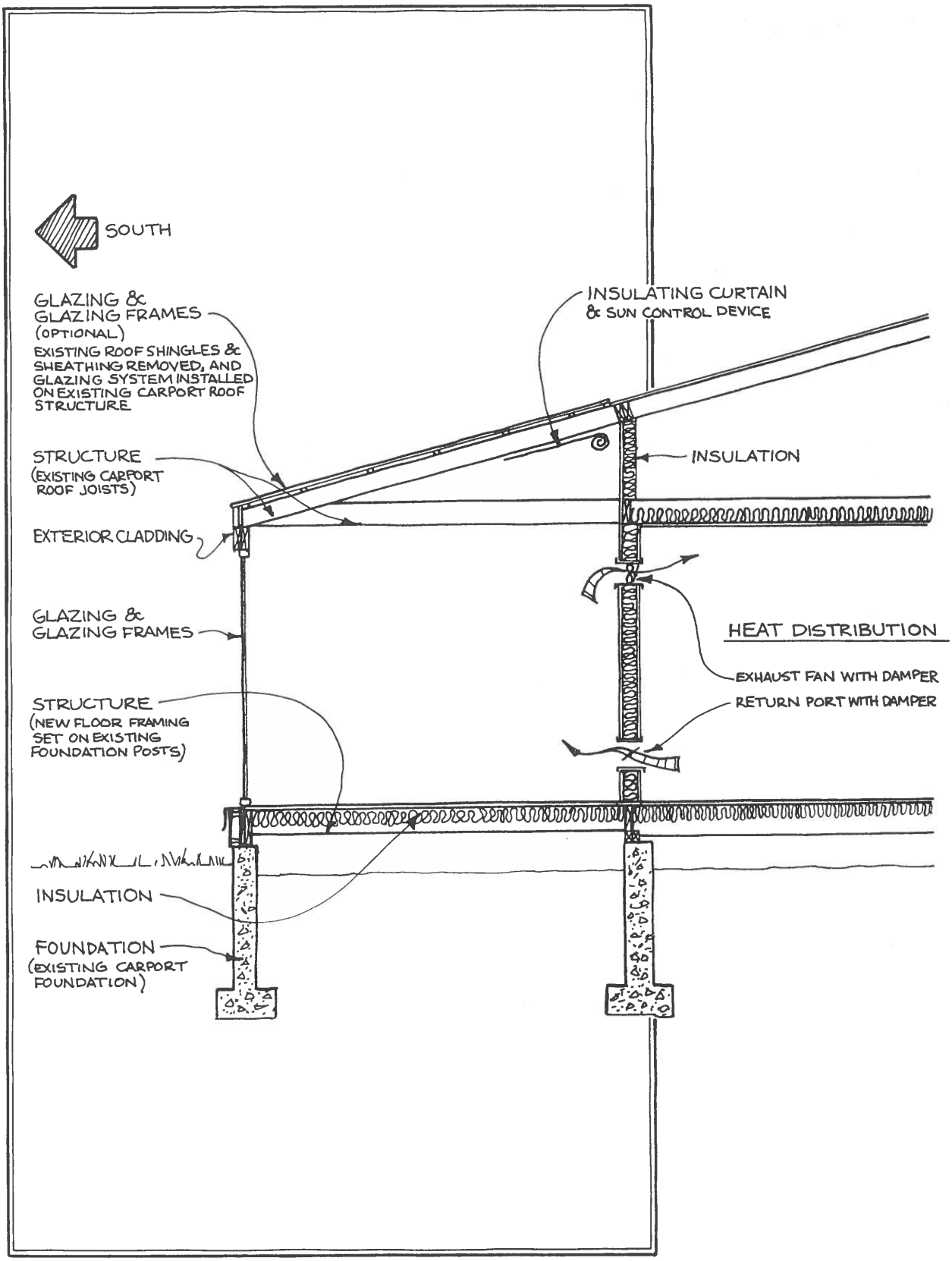
Assuming the solarium is to be used in the summer, it would be wise to design the glazing so that it either opens completely or can be dismantled. In any case, large vents and sun-shading devices will probably be necessary to avoid overheating.

A gentle inclination of the upper glazing makes this surface more effective in transmitting summertime rather than wintertime solar radiation. With its low thermal resistance, the roof glazing would be a net heat loser in winter, while contributing to overheating in summer. It would therefore be better either to make this an insulated, opaque section, or give it a steeper slope (which would mean insulating the attic wall). Alternatively, movable insulating panels could be used to cover the sloped glazing in winter.





Solarium Design Example 2

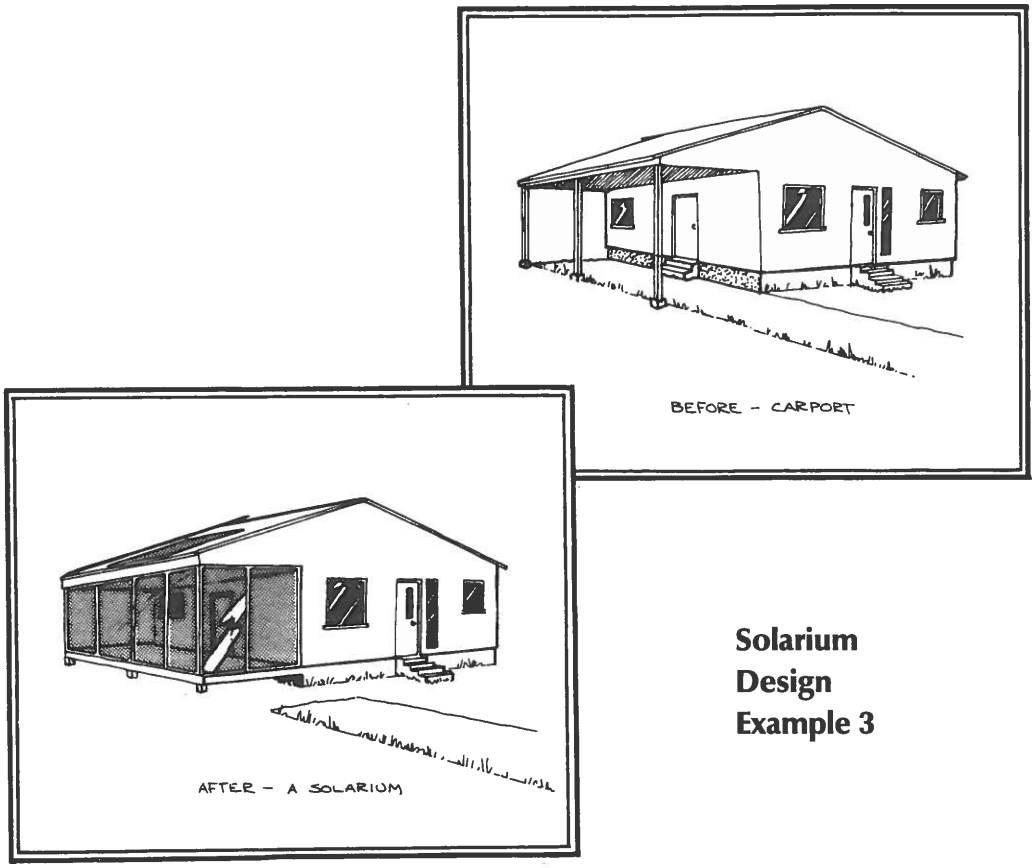

SOUTH
GLAZING & GLAZING FRAMES (OPTIONAL)
EXISTING ROOF SHINGLES & SHEATHING REMOVED, AND GLAZING SYSTEM INSTALLED ON EXISTING CARPORT ROOF STRUCTURE
INSULATING CURTAIN & SUN CONTROL DEVICE
STRUCTURE (EXISTING CARPORT ROOF JOISTS)
INSULATION
EXTERIOR CLADDING
GLAZING & GLAZING FRAMES
HEAT DISTRIBUTION
EXHAUST FAN WITH DAMPER
RETURN PORT WITH DAMPER
STRUCTURE (NEW FLOOR FRAMING SET ON EXISTING FOUNDATION POSTS)
INSULATION
FOUNDATION (EXISTING CARPORT FOUNDATION)

3. Conversion of a Carport

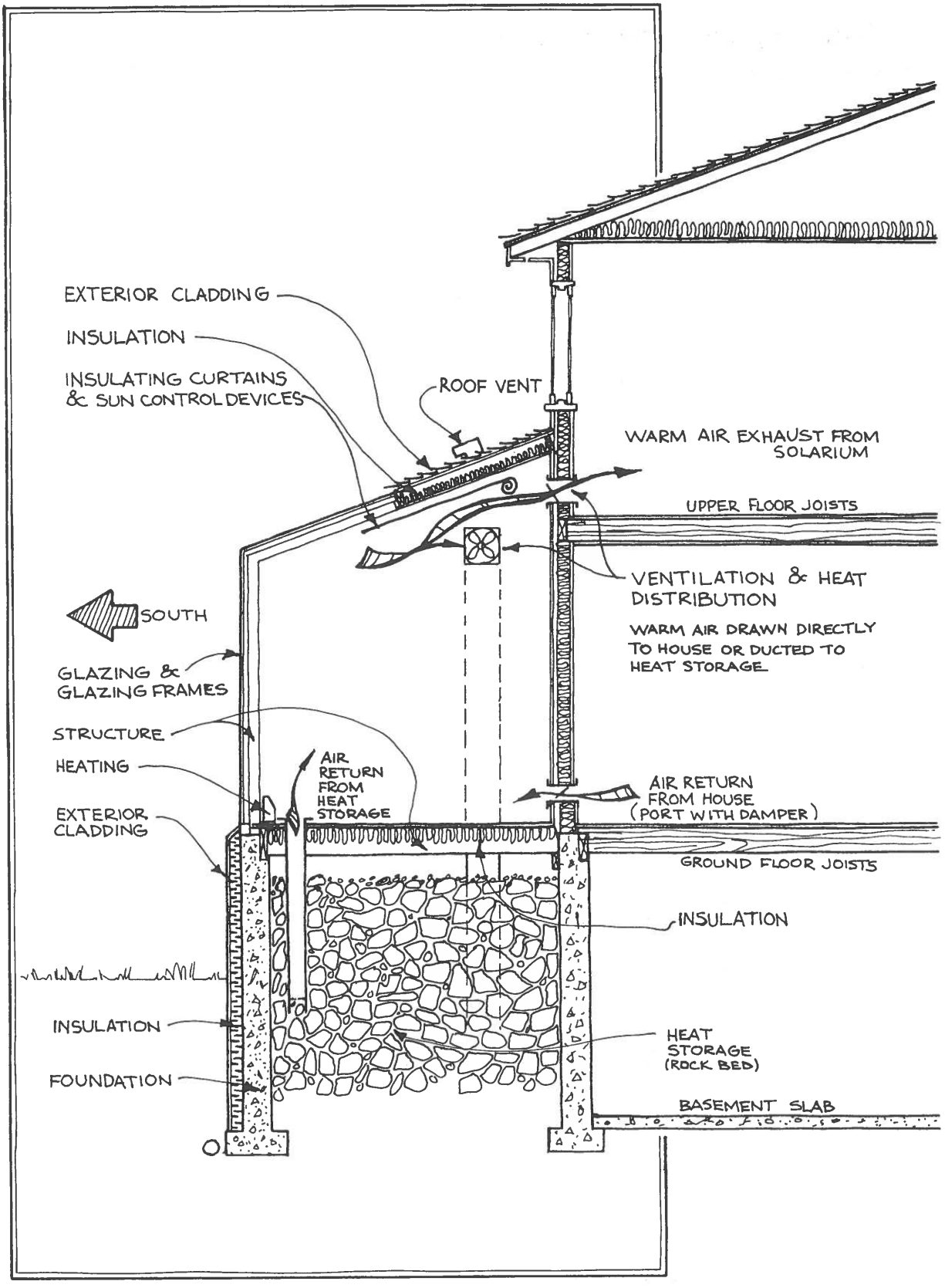
Solarium Type: Heat supplier
Air Distribution: Active Ventilation
Thermal Mass: No

An exterior space that already has a good support structure and roof may be closed in and turned into a solarium. A translucent roof can replace the existing one for greater daylighting.

However, in this particular example, the existing roof angle is too low to make roof glazing worthwhile from an energy point-of-view. Consequently, the roof-glazing material should be chosen for its ability to diffuse the direct sunlight and resist heat loss, rather than for its high transmissivity. Patio doors might be chosen for the vertical glazing as they provide a simple system for ventilation.



Solarium Design Example 3


EXTERIOR CLADDING
INSULATION
INSULATING CURTAINS & SUN CONTROL DEVICES
ROOF VENT
WARM AIR EXHAUST FROM SOLARIUM
UPPER FLOOR JOISTS
VENTILATION & HEAT DISTRIBUTION
WARM AIR DRAWN DIRECTLY TO HOUSE OR DUCTED TO HEAT STORAGE
SOUTH
GLAZING & GLAZING FRAMES
STRUCTURE
HEATING
EXTERIOR CLADDING
AIR RETURN FROM HEAT STORAGE
AIR RETURN FROM HOUSE (PORT WITH DAMPER)
GROUND FLOOR JOISTS
INSULATION
INSULATION
HEAT STORAGE (ROCK BED)
FOUNDATION
BASEMENT SLAB

4. Addition on a South-Facing Wall

Solarium Type: Heated Space
Air Distribution: Passive Ventilation
Thermal Mass: Yes

An addition to a south-facing wall is the most common solarium style and the one for which there is the most information available.

Since the construction of the requisite perimeter foundation will often make this solarium too expensive to repay its initial cost in energy savings alone, it is better to design it as a living space as well.

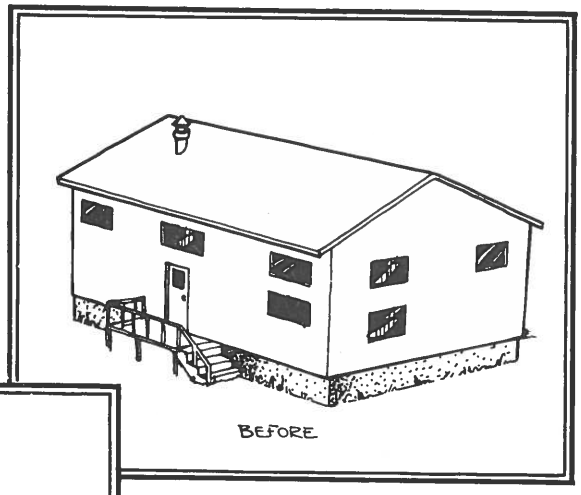
Heat storage using thermal mass is suggested since the additional cost is slight once the foundation is required. If you dig the foundation, it might also be used as an extension to the basement.

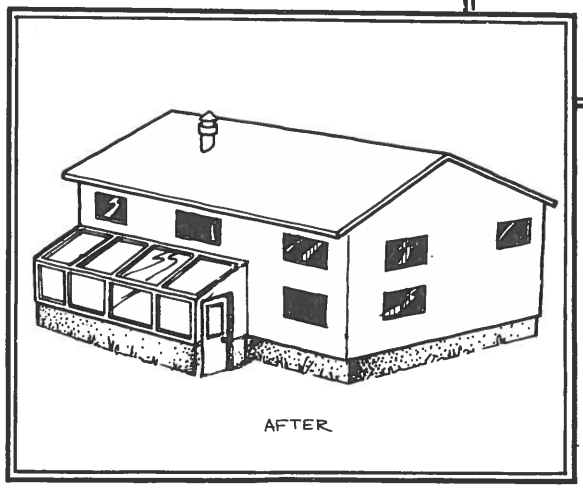
The slope of the solarium roof is parallel to the slope of the house roof for aesthetic reasons. However, a glazed panel with a steeper inclination would be more efficient for collecting solar energy in winter.

Part of this solarium roof is opaque rather than glazed to:
- reduce the chance of overheating in summer;
- resist the impact of snow and ice falling from the roof above;
- and reduce heat losses, since the opaque section is insulated.

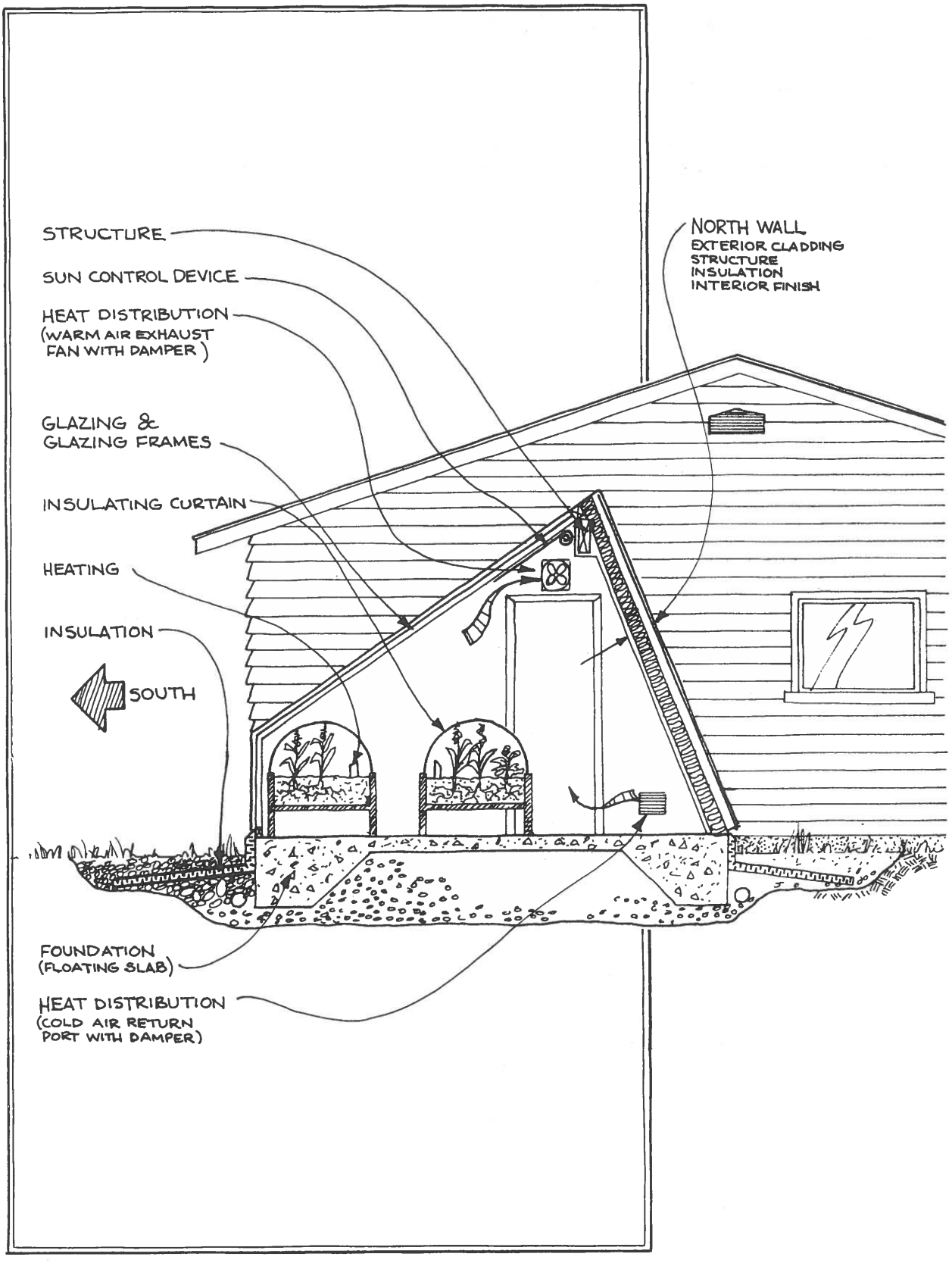
Note that this roof portion may require ventilation to prevent condensation.

The entire solarium also requires ventilation to avoid overheating when neither the house nor the solarium needs heat.





Solarium Design Example 4


STRUCTURE
SUN CONTROL DEVICE
HEAT DISTRIBUTION
(WARM AIR EXHAUST
FAN WITH DAMPER)
GLAZING &
GLAZING FRAMES
INSULATING CURTAIN
HEATING
INSULATION
SOUTH
NORTH WALL
EXTERIOR CLADDING
STRUCTURE
INSULATION
INTERIOR FINISH
FOUNDATION
(FLOATING SLAB)
HEAT DISTRIBUTION
(COLD AIR RETURN
PORT WITH DAMPER)

5. Addition on an East-Facing Wall

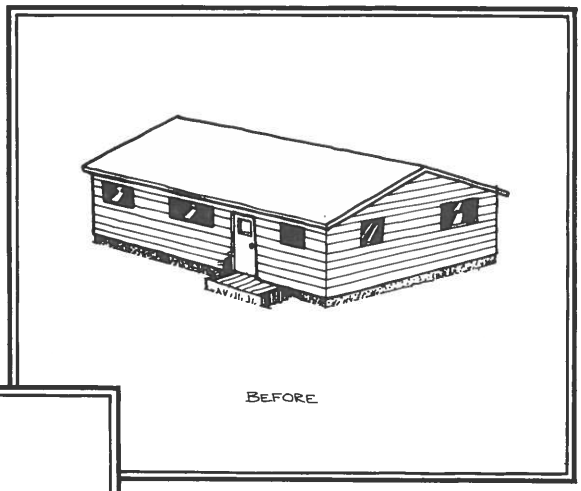
Solarium Type: Heated Space
Air Distribution: Active Ventilation
Thermal Mass: Yes

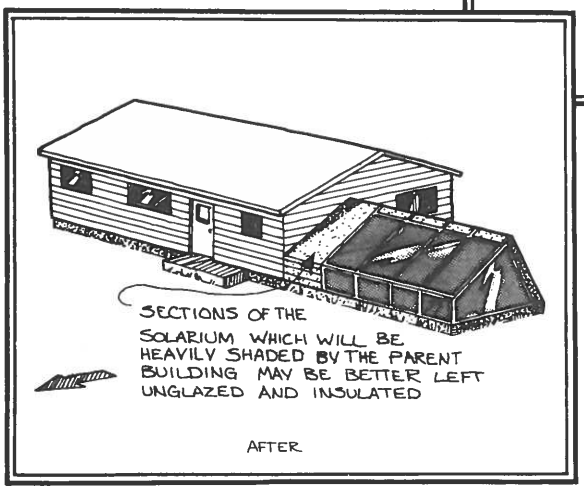
An east-facing wall, as shown, is another location for a solarium. It should be positioned as close as possible to the south face of the parent building to avoid the shadow cast by that building. Sections of the solarium which will be shaded are better left unglazed and insulated.

The slope of the glazed face shown is appropriate for the year-round cultivation of plants. However, if its principal use is the collection of solar energy, the glazing should be at a steeper angle. In this way, it receives the greatest possible radiation in winter when the sun is low in the sky. Because of high insolation during warm weather, sun control devices and ventilation to the exterior are necessary.

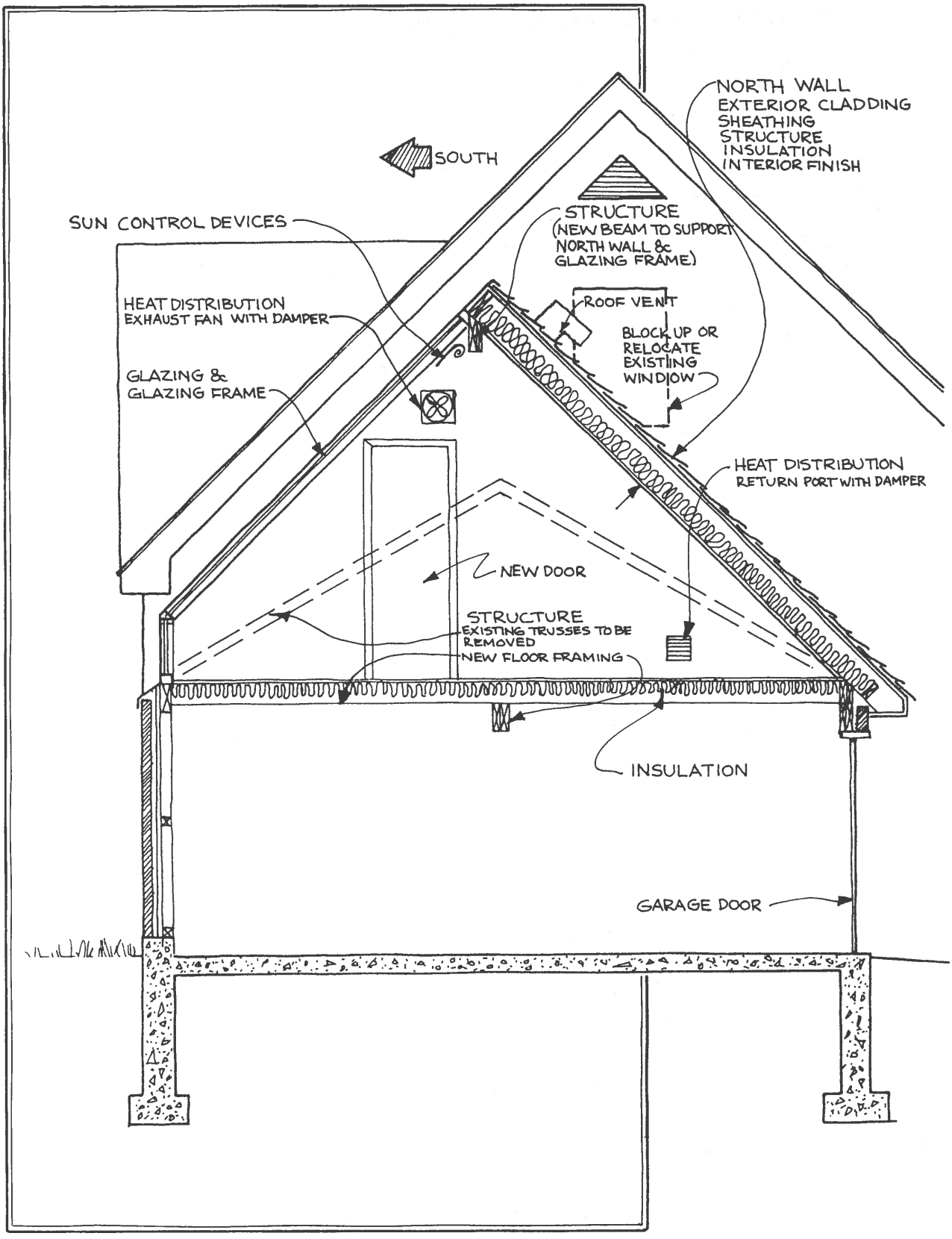
The foundation shown is a floating slab. This type is more economical than a perimeter foundation, but it can only be used with certain types of soil. Because the slab thickness and reinforcements are also critical, such a foundation should be designed by an engineer.

Heating the solarium at night will tend to offset the value of the energy collected during the day. To reduce the nighttime heat loss, insulating curtains can be used, or, as in the drawing, plants can be covered so only the space immediately surrounding them need be heated.




SECTIONS OF THE SOLARIUM WHICH WILL BE HEAVILY SHADED BY THE PARENT BUILDING MAY BE BETTER LEFT UNGLAZED AND INSULATED
AFTER

Solarium Design Example 5

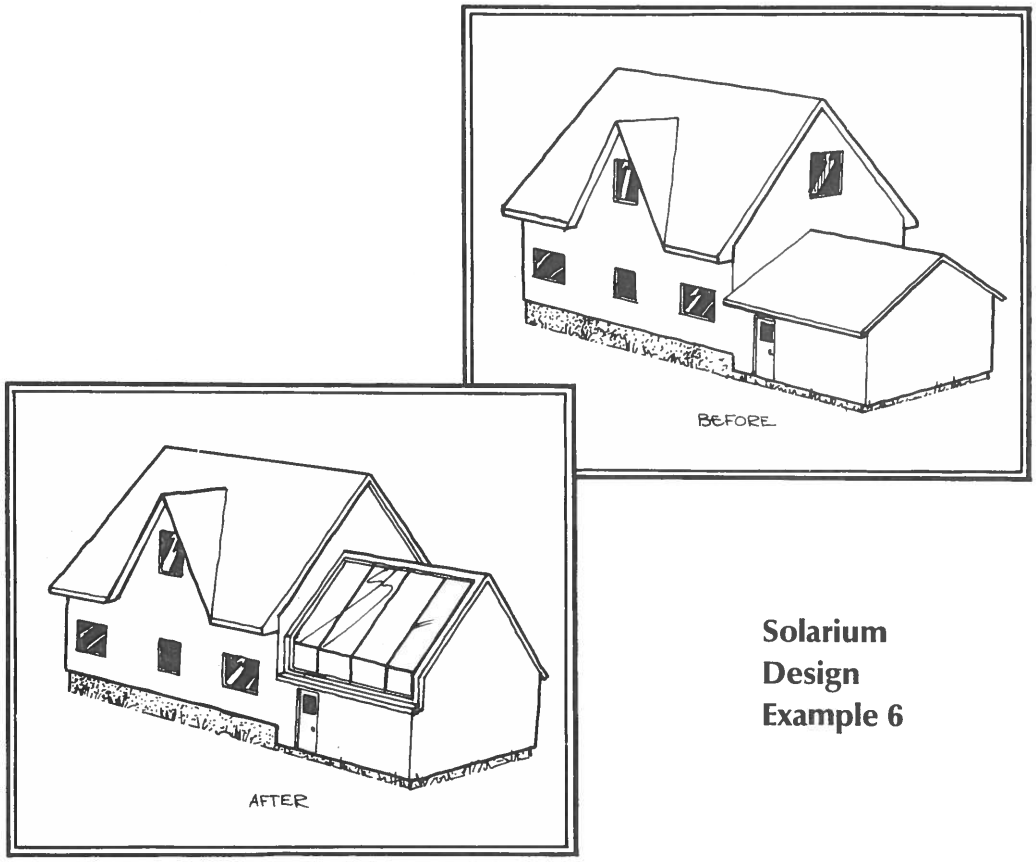

NORTH WALL
EXTERIOR CLADDING
SHEATHING
STRUCTURE
INSULATION
INTERIOR FINISH
SOUTH
SUN CONTROL DEVICES
STRUCTURE
(NEW BEAM TO SUPPORT
NORTH WALL &
GLAZING FRAME)
HEAT DISTRIBUTION
EXHAUST FAN WITH DAMPER
ROOF VENT
BLOCK UP OR
RELOCATE
EXISTING
WINDOW
GLAZING &
GLAZING FRAME
HEAT DISTRIBUTION
RETURN PORT WITH DAMPER
NEW DOOR
STRUCTURE
EXISTING TRUSSES TO BE
REMOVED
NEW FLOOR FRAMING
INSULATION
GARAGE DOOR

6. Addition Over an Existing Garage

Solarium Type: Heat Supplier
Air Distribution: Active Ventilation
Thermal Mass: No

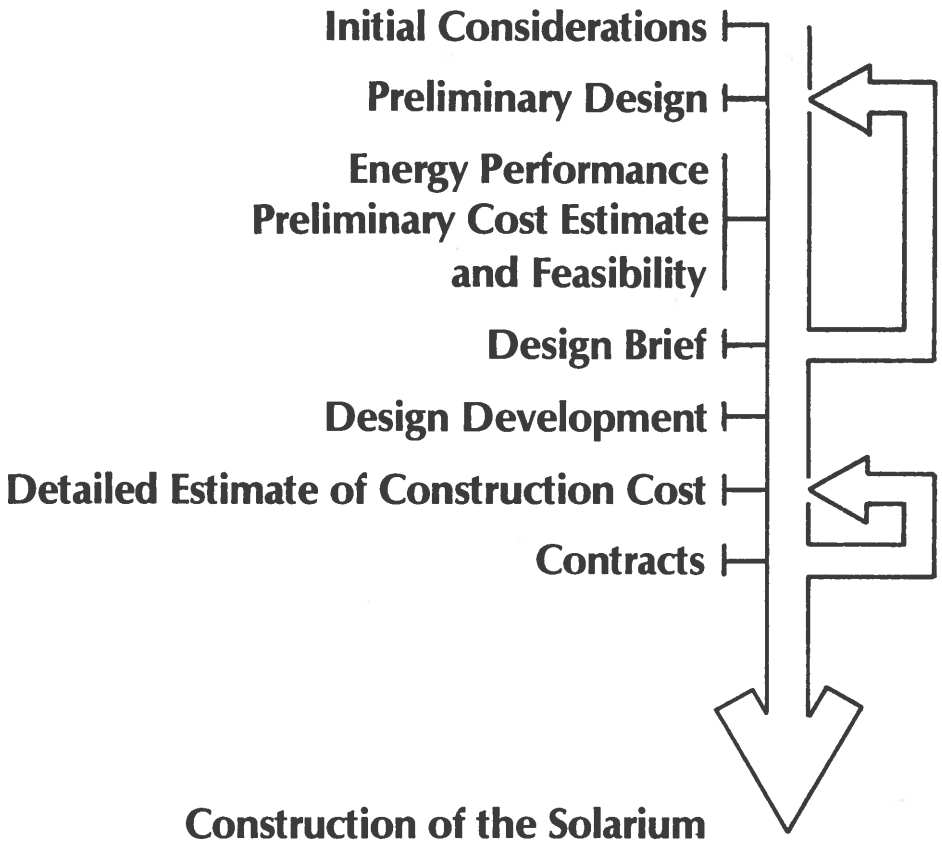
A solarium can be built onto the top of an existing portion of the house, such as a garage, if there is adequate structure to support it. This design is similar to the conversion of a carport. In this case, however, you may have to consider relocating existing doors or windows.

Since a garage is usually an unheated space, you will have to insulate the floor between the garage and the solarium to minimize heat loss.



Solarium Design Example 6

The Design Process



There are many publications which may be helpful for anyone planning work of this nature. They are listed at the back of the book. Many are quite inexpensive and some may be found in libraries.

Generally, construction projects should follow a logical progression from concept to realization. This section gives a general overview of the stages which are covered in detail in subsequent chapters.

Up to the construction stage, the process is not strictly a sequential one since re-evaluation of a preceding stage may occasionally be necessary. The effect of such changes must be carefully considered in relation to the overall project. All these decisions should be made before the award of a contract because changes made after this point can be very expensive.

From start to finish your solarium project can be divided into the stages indicated on the above diagram.

Initial Considerations

The first questions to ask yourself are:

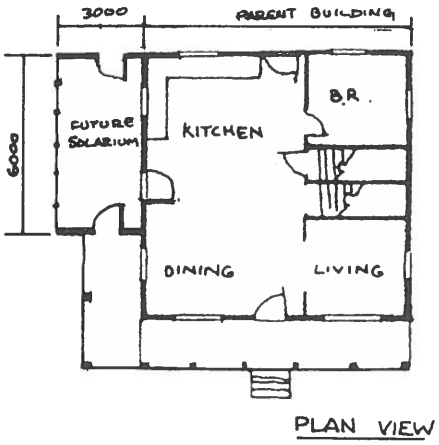
1. Is the proposed site suitable for a solarium?
2. What local building regulations apply?
3. For what purpose is the solarium to be used?
4. What design considerations relate to the proposed use?

These issues are discussed in Chapter 2.

Preliminary Design

At this stage, the project should be defined generally in sketches and notes. Keep in mind your objectives and the solarium's effects upon the building it adjoins as you establish its size and configuration. Next, determine the size and orientation of the glazed surfaces.

This aspect of the work is covered in Chapter 3.



PLAN VIEW

Evaluation of the Preliminary Design

After you have a preliminary design, you will be ready to consider its energy efficiency and cost-effectiveness. At the same time, however, you might want to keep in mind that qualitative benefits, such as added comfort, can often override economic factors in home-improvement projects.

The solarium's effectiveness as a heat producer is explored in Chapter 4.

Design Brief

The next step is the preparation of a design brief. This is simply a written description of the objectives of the project, a definition of the installation required, and something about the manner of its execution. It does not detail the work to be performed, but it is useful as a basis for the design.

Chapter 5 expands on this stage.

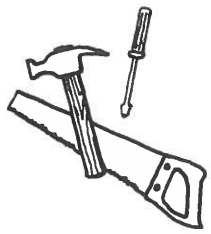
Design Development

Now you need a set of drawings to give a precise definition of the work and equipment required.

At this point you are ready to make a final cost estimate, which should be reasonably close to the final cost of the project. If you have exceeded your budget, the design may have to be changed. Your estimate will also serve as a comparison for any contract bids submitted.

Chapter 6 discusses these points in detail.

Contracts and Materials



If any of the work is to be performed by others, you will need to define very clearly the work and its manner of execution before you invite tenders. If you are going to do the work yourself, you will need to compare costs of supplies.

All this is covered in Chapter 7.

Construction

At this stage, you are ready to begin actual installation of the solarium.

CHAPTER 2
INITIAL CONSIDERATIONS

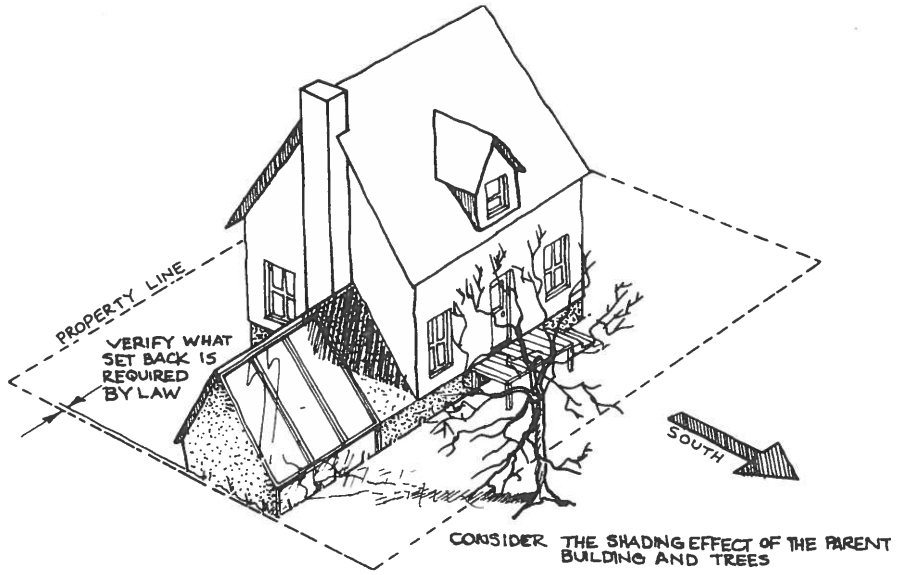
Objectives

A solarium can be simply a collector of energy for the parent building, or it can be a games room, a work room, or a greenhouse.

In the latter case, the energy performance of the solarium will probably have to be compromised to accommodate the planned activities. You must decide, therefore, which function is most important to you, or to what extent you are willing to compromise energy performance for additional living space. Keep in mind that even a simple, uninsulated solarium will be a comfortable temperature at least on every bright, sunny day of the winter, making it a nice daytime sitting room.

Site Suitability

Environmental Shade


PROPERTY LINE
VERIFY WHAT SET BACK IS REQUIRED BY LAW
SOUTH
CONSIDER THE SHADING EFFECT OF THE PARENT BUILDING AND TREES

Environmental shading of the proposed solarium must be assessed at the outset. While the solarium will collect energy from diffuse solar radiation, most of the energy collected will be from direct radiation, so anything interfering with reception must be carefully considered.

Undesirable shading can be caused by trees, bushes, topographical features and buildings, including portions of the parent building itself. The shade pattern will change daily with the movement of the sun and with the changing seasons. The pattern will also depend on whether the trees and bushes are covered with foliage and upon the growth patterns.

Of course, shading can, at times, be desirable—especially in the heat of summer. A deciduous tree will provide summer shade without posing a serious obstruction to solar radiation in winter. Climbing vines along the outside of the solarium will serve the same purpose.

You may conduct a preliminary evaluation of the effect of the shading on the potential site of the solarium by inspecting the site visually on sunny days, or by using the sun-path diagrams given in appendix A.

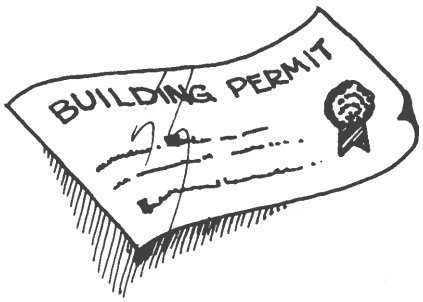
You should also consider potential shading caused by future buildings near your site. Alternatively, you may consider removing a building or trees to increase the amount of direct sunlight received.

Additional Thoughts

You should assess the site for inherent restrictions, such as impeded access for any purpose, potential damage by activities normally taking place in the area, and vandalism. For example, it would not be wise to build a solarium next to a baseball diamond!

Most buildings must comply with some form of federal, provincial or municipal regulation. They may also have to conform to standards set by insurance companies and by financial institutions if a mortgage or loan is involved. Sometimes the deed of land has restrictive covenants preventing certain additions or changes to a structure. City Hall is a good source of all such information.

Building Regulations



You will probably need a building permit from your municipality's building inspector before you commence construction. The building permit, however, is not a structural or performance guarantee, so you must make sure that both the design and the construction are done by qualified people.

The local building inspector will also check the project during construction to ensure it conforms to local bylaws. Some of the regulations you must meet are:

Zoning

Zoning might, for instance, prevent the use of your solarium as a commercial greenhouse.

Building Code

A building code is a set of regulations concerned with both the spatial design and the construction of buildings. It may stipulate which materials may be used for each element of the building and the manner in which they are assembled. Most (but not all) municipalities use the National Building Code of Canada, but check first.

Size

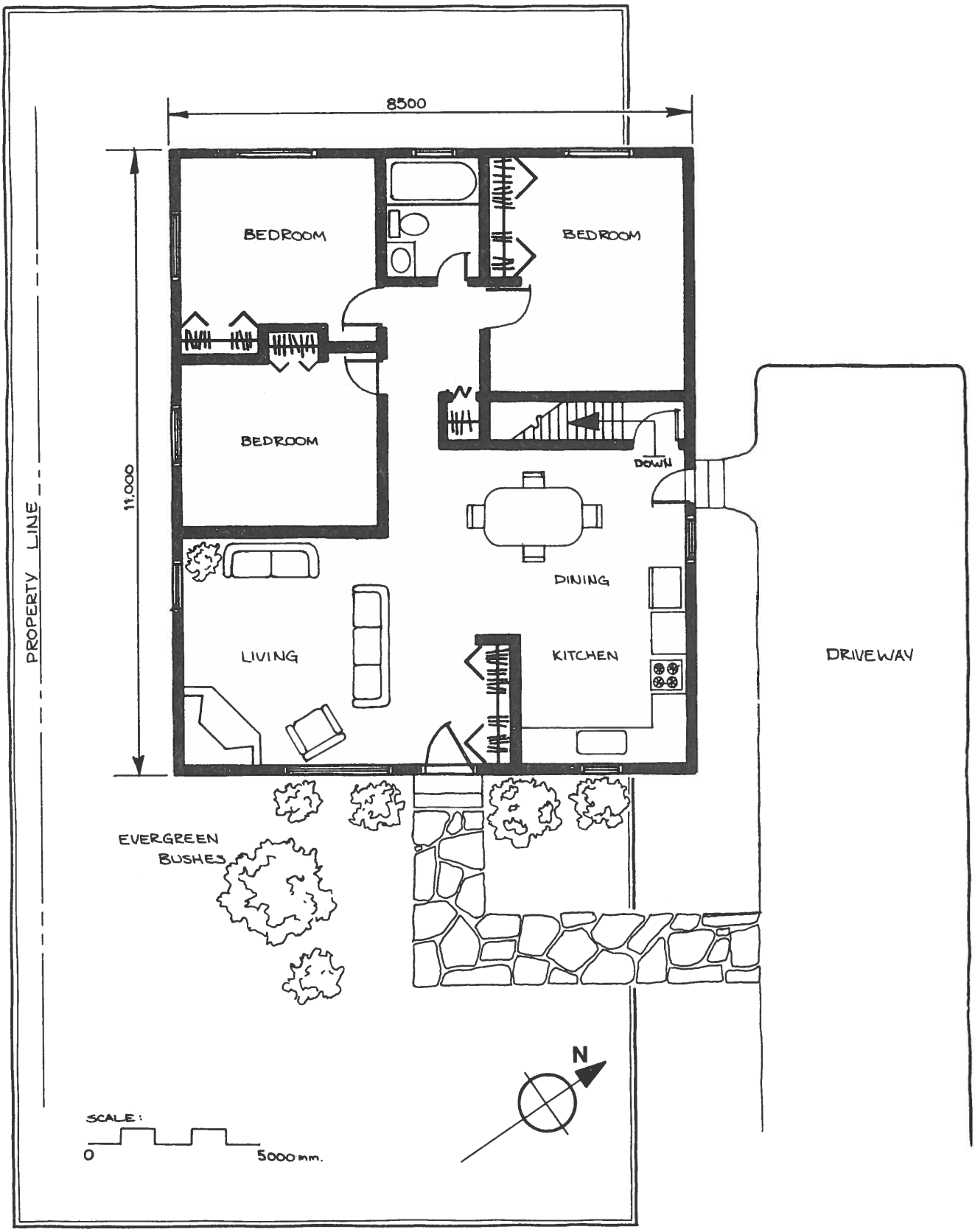
A bylaw may stipulate only a certain portion of the property can be covered by buildings.

Placement

Bylaws usually require buildings be placed a certain distance from the property line and from the street.

Safety and Health

Check the building code for any safety and health regulations that might apply in your case. This is extremely important if the solarium is to be used for commercial purposes.


8500
11,000
PROPERTY LINE
BEDROOM
BEDROOM
BEDROOM
DOWN
DINING
LIVING
KITCHEN
DRIVEWAY
EVERGREEN
BUSHES
N
SCALE:
0
5000 mm.

Civil Law

Some provincial and federal laws exist to guarantee the rights of neighbours and to protect the public interest. Local building inspectors are usually familiar with these requirements so it is best to check with them. Architects, or licensed engineers can also provide such advice.

Financing, Taxes and Insurance

If you require a loan to finance the construction of your solarium, check with your bank before you begin your project.

You should note that while the solarium will probably increase the value of your property, it may also increase the property taxes.

You should also check with your insurance company for any other special requirements.

Architectural Considerations

Energy Performance of the Parent Building

Before constructing a solarium you should give careful consideration to the energy efficiency of the parent building. You may find problems which could be solved simultaneously with the addition of the solarium.

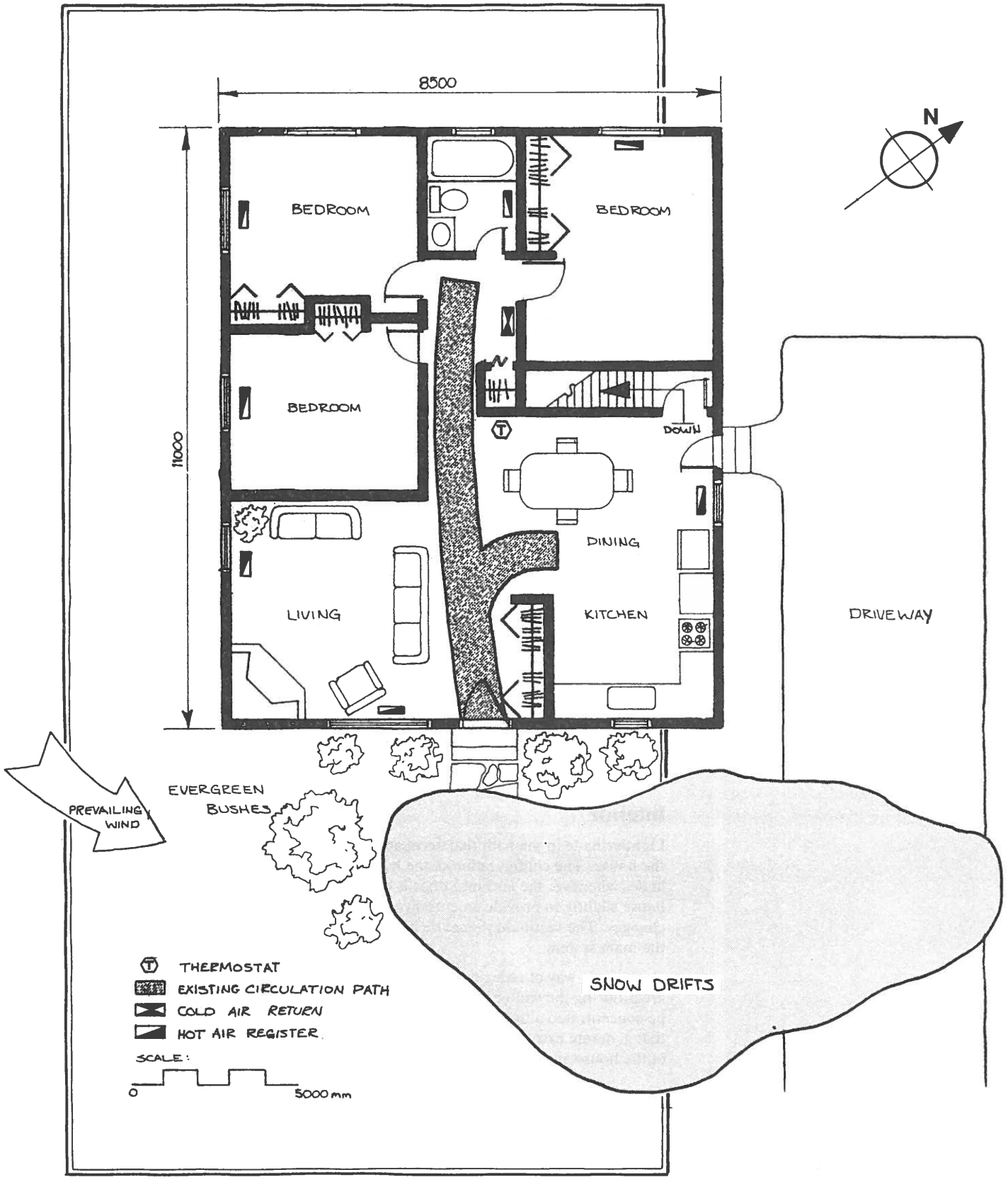
There are many publications available which are concerned with the energy performance of a building, such as:
The Conservation of Energy in Housing from Canada Mortgage and Housing Corporation;
Keeping the Heat In, from the Office of Energy Conservation, Energy, Mines and Resources Canada, and;
Solplan 2 by the Drawing-Room Graphic Services Limited.

If you wish to carry out a detailed evaluation of your building, it is best to refer to these sources. However, a simple evaluation of your building's energy consumption may be adequate.

Begin with a floor plan drawn to scale. Draw plans of each level of the house at a scale large enough to show everything clearly, yet small enough to show the whole site on the ground-floor plan. Use a scale of 2 centimetre to 1 metres, (or one-quarter inch to one foot). It is useful to indicate walls as having thickness rather than as a single line. Measurements should be made to the nearest centimetre and drawn to scale to the nearest few centimetres. You should find it easier to make rough sketches first, make your measurements and then draw clearer plans to scale. Indicate the scale on each plan.

Present energy consumption

This can be done simply using your utility bills from previous years. If your records are sufficiently detailed, you can calculate your average energy consumption for each month of the heating season. This calculation will be used later in the performance calculations for your solarium design. It is important to adjust the energy-consumption figures to account for equipment or appliances that do not contribute to space heating. The electrical consumption of many household appliances is given in *The Conservation of Energy in Housing*. As well compare your present fuel consumption to that of a similar building discussed in the book. This will indicate whether or not you should first upgrade the energy performance of your home.


8500
11000
N
BEDROOM
BEDROOM
BEDROOM
DOWN
DINING
LIVING
KITCHEN
DRIVEWAY
PREVAILING WIND
EVERGREEN BUSHES
SNOW DRIFTS
THERMOSTAT
EXISTING CIRCULATION PATH
COLD AIR RETURN
HOT AIR REGISTER
SCALE:
0
5000 mm

Insulation

Refer to the free publication, *Keeping the Heat In,* for a discussion of insulation and weatherproofing methods.

Heating System

Refer to the free publication, *The Billpayer's Guide to Furnace Servicing,* from the Office of Energy Conservation, Energy, Mines and Resources Canada, for a discussion of maintenance and repair procedures for oil and gas heating systems.

On the plan indicate areas regularly found to be colder or warmer than the rest of the house in winter. Uneven temperatures inside the house may be caused by poor air circulation or weak natural convection currents. A fan may be necessary to achieve a more regular distribution.

Indicate the positions of thermostats. If they are located where there is a cold draft or an accumulation of warm air, they will not control the heating system properly.

Indicate on the plan position and size of heating elements. If these are poorly sized for the spaces they supply, the system may be unbalanced. A strong heat supply at the bottom of a stairwell may overheat the floor above.

Site

You can obtain weather data from Environment Canada for many stations across Canada to get wind direction(s) and speed(s) in your area. You should also consider your own experience of the wind(s) on your site.

Indicate on the ground floor plan the direction(s) of the prevailing winter wind(s) and maximum gusts. Any windbreaks should also be indicated on the plans. Describe them briefly and record their approximate heights.

Indicate where snow normally accumulates in drifts and the areas that must be cleared of it.

The information you have recorded on your site plan may suggest the need for windscreens to shelter the site and control snow drifting. It may also indicate a need to change the location of the main entrance in winter, though this may be very difficult to achieve in practice.

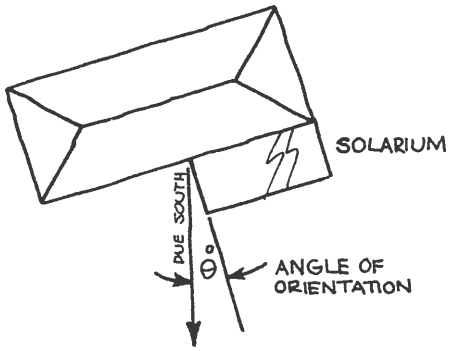
Interior

Lightly shade in the path that occupants frequently follow on trips in and out of the house. The configuration of the house could be such that there are large heat losses whenever the entrance door is opened. It may be possible to renovate your house slightly to provide an entrance vestibule, to reduce the number of air changes. The vestibule should be heated by a separate heater independent from the main system.

One simple way of reducing heating costs is to close off and not heat little-used areas during the winter. Rooms that require less heat, such as bedrooms, should be concentrated along the north wall where heating is more expensive. Activities that generate extra heat, such as the laundry, should be located on the north side of the house as well.

Passive Solar Heating

Indicate the orientation of the house in relation to solar south on each plan. Indicate the dimensions of all the windows of the house. Heat loss through these windows may be calculated as explained in *The Conservation of Energy in Housing*. Solar heat gain can be calculated using the method described in Chapter 4. The size of the north-facing windows can be reduced down to 10% of the floor area of the corresponding room to minimize heat loss while maintaining a reasonable level of illumination in the room.



Solar heat gain may be increased by enlarging the windows facing south. However, the following points should be kept in mind:

- Insulated shutters should be provided to cover the windows at night during the winter.

- Sun-shade devices sould be used in the summer to avoid overheating of the house (deciduous trees, awnings, roof overhangs, shutters, etc.)

- Interior finishes and furniture should not be suceptible to fading or other damage by radiation.

- Large south-facing windows in small rooms will produce overheating. Such windows should be in large spaces, or alternatively, a fan should be used to ventilate the hot air to the rest of the house.

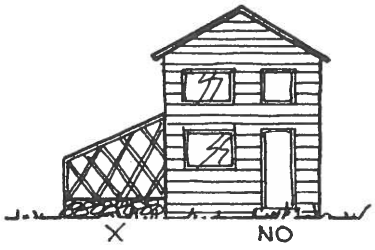
- The solar heat gain may be made more effective by proper distribution of thermal mass within the house. Massive elements should be placed in the path of direct solar radiation in winter to absorb energy during the day and release it as heat during the night.

Suitability of the Parent Building

The building to which the solarium is to be attached must be in good condition and structurally sound, especially if it is to support all or part of the new structure. Repair and reconstruction of the existing structure should be the first step.

This is not limited to the structural elements and foundations. All non-structural elements to which the solarium will be attached, such as the roof surfaces, soffits and wall claddings, must be in good condition.

You should also be aware that when a building is renovated, the building inspector requests the older building conform to current codes and requirements. This could have major cost consequences, especially for renovated commercial structures, since alterations such as better fire exits may be required.



Aesthetics

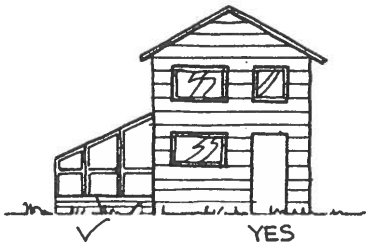
Your solarium should add to the appearance of the parent building. Although aesthetics are not simply defined, some general rules do apply.

The lines of the solarium should conform to those of the existing structure whenever possible. For example, it may be possible to make the slope of the solarium roof the same as that of the existing roof.

The exterior finishes of the unglazed surfaces of the solarium should match those of the existing building.

Where a solarium could be located anywhere along the side of the parent building, it should appear to be a natural extension of that building.

In general, the solarium should not radically alter the character of the existing structure.



CHAPTER 3
PRELIMINARY DESIGN

When you have settled the basic requirements established in Chapter 2, a preliminary design can be made. This consists of sketches, to scale, showing:
- The outline and major dimensions of the solarium.
- The extent, orientation and inclination of the glazed surfaces.
- Major structural features such as foundations, floor, walls and roof.
- Any modifications required for the existing building.

Preliminary sketches define the design concept as precisely as possible, without restricting or eliminating any options that may be investigated later.

The following decisions should be made during this stage:

- Where will the solarium be located?
- What type of solarium will it be?
- What will its dimensions be?
- During what season will the energy performance be most important?
- During what time of day will the solarium's performance be most important?
- Who will design and build the solarium?

These decisions in turn will influence the design features of your solarium:

- Will insulating curtains and auxiliary heating be necessary?
- Will it require a large thermal mass?
- What will be the glazing inclination and orientation?
- What will be the inclination of the rear wall?
- Will the east or west wall be glazed?
- Will blinds be necessary?
- Are there particular materials you prefer?

All these decisions affect the preliminary design and affect each other. As the work progresses, notes should be made outlining the background for your decisions, as well as pertinent design information such as material specifications and construction details. These notes can be shown neatly on the sketches or kept in a file used in conjunction with the sketches.

The following sections should help you make the right decisions to suit your specific requirements and objectives.

Design Considerations

Types of Solaria

A basic decision should be taken at the outset of the project as to what type of solaria is best suited to your needs. The following table gives a review of the different features which are determined by that choice.

The choice of a heat distribution system will also be influenced by the type of design as discussed in Chapter 1.

Table 3-1: Solarium Design Features

Equipment	Type 1 Supplier of Heat	Type 2 Heated Space	Type 3 Supplier of Heat with Occasional Heating
Thermal Mass	Undesirable	Desirable	Undesirable
Auxiliary Heating	Unnecessary	Necessary	Necessary
Insulating Curtains	Unnecessary	Necessary	Optional
Glazing on East or West Walls	Must be determined by calculation	Optional	Must be determined by calculation
Blinds	Optional	Optional	Optional
Sun-Control Devices	Desirable	Necessary	Necessary
Ventilation to Outside	Desirable	Necessary	Necessary
Heat Distribution to Parent Building	Necessary	Optional	Necessary

Solarium Design and Construction

Some decisions concerning the construction of the solarium may have an influence on the preliminary design. If, for example, you select a solarium kit, you must choose one that fits your requirements exactly, or be prepared to provide the skill and equipment necessary to modify the kit. Alternatively, you may decide to change your design to accommodate the kit.

Therefore, you must take into account the organization and execution of the design and construction of the solarium right at the preliminary design stage.

1. You may design the solarium yourself, purchase the materials, and carry out the construction work. Or, you might hire skilled people for the trades in which you may not be competent or for which a licensed tradesman is required by law.

2. You may decide to purchase a solarium kit which conforms generally to your requirements. There are many such kits on the market and they can be supplied with such accessories as ventilators, fans or heaters. You should determine exactly what the kit consists of and what you must supply (e.g., concrete foundations). You may carry out the installation yourself or have all, or some of the work done by others. When pricing or enquiring about kits, it may help to provide the manufacturer with a copy of the preliminary sketches.

3. You may decide to hire others to design and build your solarium completely. If so, you must establish very clearly your requirements before talking to prospective designers and contractors.

4. Some organizations conduct solar greenhouse construction workshops in which the owner pays for the materials and the participants provide free labour in exchange for the learning experience. There is usually an entrance fee which pays for the workshop leaders.

In order to help you make this decision, Table 3-2 shows how costs vary with the method of construction.

Table 3-2:

Cost Per Unit Area for Different Designs and Construction*

Solarium Type	Technical Content	Installation Procedure	Anticipated Cost $/m²
Custom designed	Architecturally designed and integrated into parent building's shape and quality	General contractor	400 to 950
Prefabricated models commercially available	Prefab units engineered and manufactured to meet basic solaria requirements	Solarium installer and general contractor	280 to 500
Prefabricated kits	Prefab frame and glazing components sold through commercial building supply outlets	Do-it-yourself installation including floor construction and foundation	150 to 400
Built from standard plans	Information package detailing proven solarium designs; probably adapted or modified to suit client's needs	Do-it-yourself or sub-contracted	150 to 350
Modified verandah, balcony, carport	Homeowner modifies existing structure	Do-it-yourself	80 to 150
Components for glazing, framing, foundations, etc.	Standard components would eventually be developed specifically for the solarium market	Do-it-yourself	100 to 190

* *Please note the cost figures provided are rough estimates only, in 1981 dollars.*

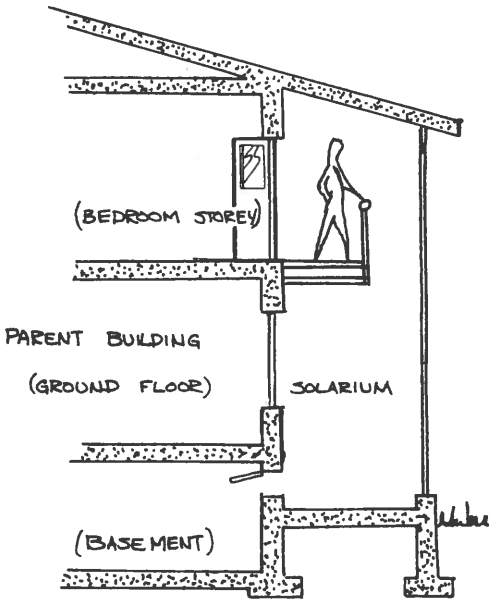
Dimensions

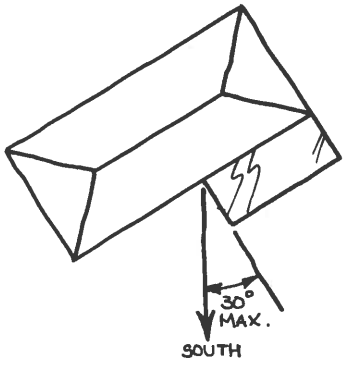
You should determine how large the solarium must be to meet your needs. It can range in size from being the largest room in the house to a small extension or even simply a new window. From an energy-savings point of view, the most important variable is the configuration of the glazing.

A foundation which is adequate for a one-storey frame building will usually be able to support two storeys. Since the foundation represents a large component of the cost of a solarium, the possibility of a two-storey solarium should be considered if the height of the parent building permits. The surface area of the glazing (and thus the solar energy to be collected) is then doubled without doubling the cost of the solarium.

While it is advantageous to maximize the area of the glazing surfaces within the solarium, it is not cost-effective to design the solarium to meet a large portion of the heat load of the parent building. Usually the size of the solarium will be determined by such factors as:

- the amount of space required for the activities to be carried on inside the solarium;
- the limits imposed by the configuration of the parent building (such as the location of existing doors and windows);
- the limits imposed by the configuration of the site;
- cost;
- aesthetics.





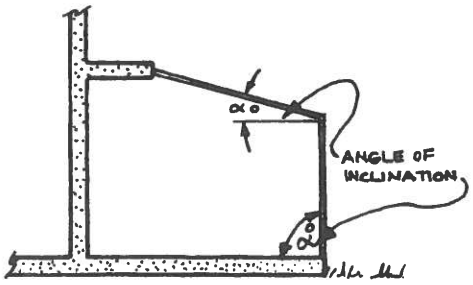
Glazing Orientation

The glazing orientation will most likely depend on the configuration of the parent building and the site. In general, the orientation should be within 30° east or west of due south. Remember that a glazed surface with an orientation greater than 30° from due south will usually lose more energy through conduction than it gains from solar radiation between October and March.

Glazing Inclination

The diagrams illustrate the effect of glazing inclination on the penetration of solar radiation for the different seasons of the year. The final choice will depend on the purpose of your solarium and on the activities which will take place inside. In general, you will want the best penetration during the heating season and minimum penetration during the summer, to reduce the chances of overheating.

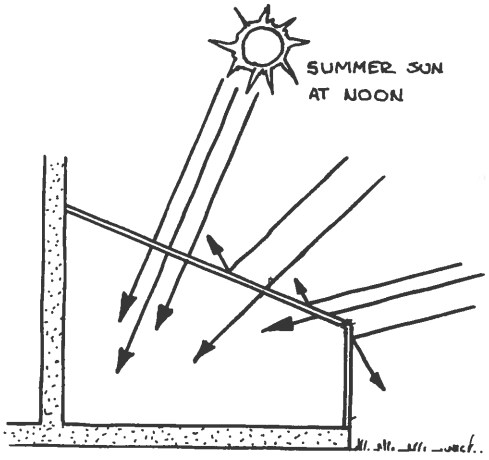
The optimum glazing inclinations suggested below have been worked out for latitude of 45°. For latitudes within 3 degrees of 45°, the departure from the suggested values is not significant.



22°

At noon on 21 June, the sun is at an altitude of 68° and the ideal glazing inclination for the reception of direct solar radiation is 22°.

This configuration requires a substantial short vertical wall, or a knee wall, to get sufficient head room inside the solarium.



Winter:
- Poor penetration of the solar radiation.
- The glazing is dangerously exposed to ice and snow falling from the roof above.
- Snow accumulates easily on the glazed roof and shades the solarium interior.

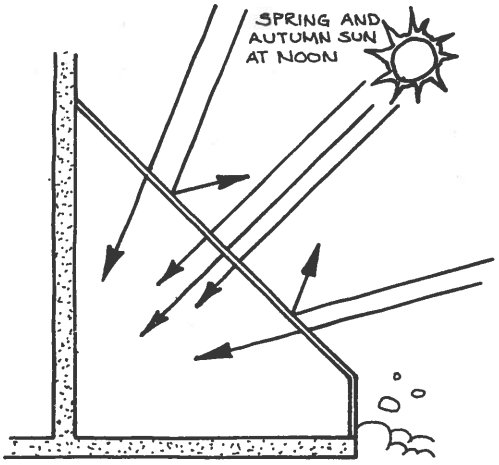
Spring/Autumn:
- Fair penetration of the solar radiation.
- No shading effect from the solarium configuration to inhibit plant growth.

Summer:
- Very high penetration of the solar radiation.
- There is no shading effect from the configuration to protect the solarium from overheating.
- Good ventilation is critical.

45°

At noon on 21 March and on 21 September, the sun is at an altitude of 45° and the ideal glazing inclination for the reception of direct solar radiation is 45°.

This configuration requires a knee wall and a high back-wall to achieve sufficient floor area and head space.



Winter:
- Fair to good penetration of solar radiation; therefore this configuration will work as a solar collector.
- The glazing tends to deflect ice and snow falling from the roof above and is therefore less likely to be damaged.

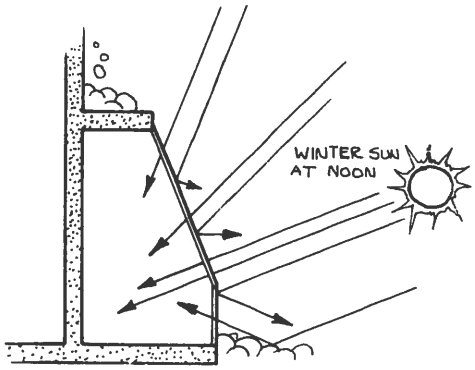
Spring/Autumn:
- Excellent penetration of solar radiation, leading to very good solarium performance as a solar collector.
- No shading effect from the structure which could inhibit plant growth.

Summer:
- Fair to good penetration of solar radiation which could lead to overheating.
- No shading effect from the structure to protect from overheating.
- Ventilation is critical.

68°

At noon on 21 December, the sun is at an altitude of 22° and the ideal glazing inclination for the reception of direct solar radiation is 68°.

This configuration allows for full use of the floor area with or without a knee wall.



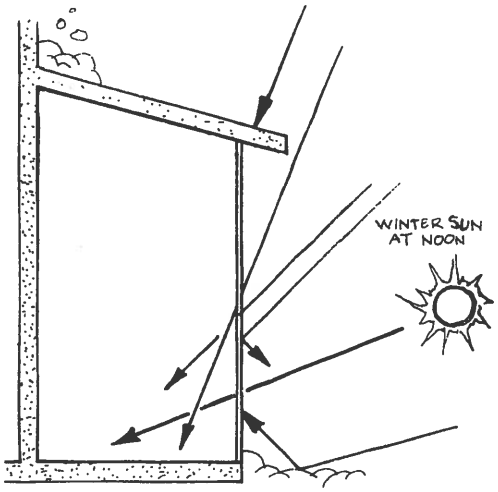
Winter:
- Excellent penetration of the solar radiation, leading to very good solarium performance as a solar collector.
- The glazing is protected from falling ice by a small solid roof.
- Snow sheds easily from the glazing.
- Some heat gain can be derived from solar radiation reflected off the snow-covered ground.

Spring/Autumn:
- Fair to good penetration of solar radiation, so the solarium would still work well as a solar collector.
- The roof portion introduces some shading of the interior space.

Summer:
- Poor penetration of solar radiation, which reduces the likelihood of overheating.
- The roof portion causes significant shading of the interior which reduces the heat gain, but which may also inhibit plant growth towards the back.

90°

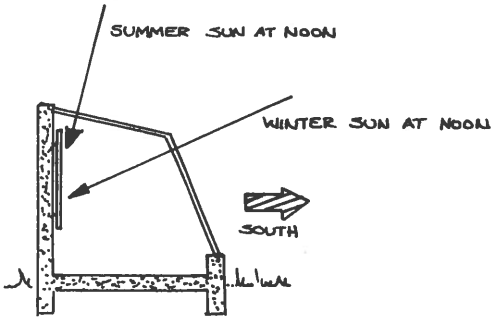
This configuration leads to the best utilization of floor space and head space. It is also the simplest, most familiar structure which may result in significant cost reductions.



Winter:
- Good penetration of solar radiation throughout the day, so this solarium configuration will work well as a solar collector.
- A significant heat gain may be derived from solar radiation reflected off the snow-covered ground.
- There is no danger of damage to the glazing from falling ice and snow, and greater spans can be used between glazing frames.

Spring/Autumn:
- Fair penetration of solar radiation, which will lead to reasonable solarium performance as a solar collector.
- The roof portion introduces shading of the interior, which may inhibit plant growth towards the back.

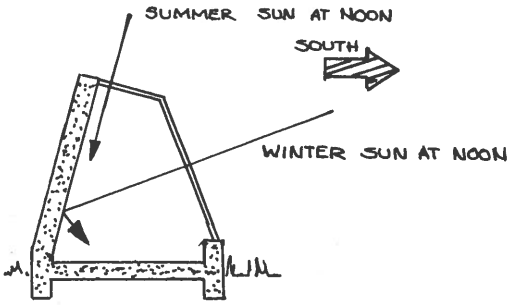
Summer:
- Poor penetration of solar radiation because of the high altitude of the sun.
- The roof portion and overhang provide good shading to protect the solarium from overheating, but may inhibit plant growth.



Inclination of the Rear (North) Wall

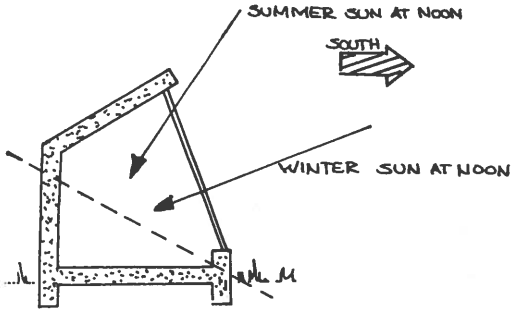
If the solarium is attached along the south-facing wall of the parent building, this wall itself will become the rear wall of the solarium and will almost always be vertical. However, if the solarium is attached along the east or west wall of the parent building, then the rear (north) wall can be inclined to suit the design.

The following diagrams illustrate four types of north walls and explain the advantages and disadvantages of each.



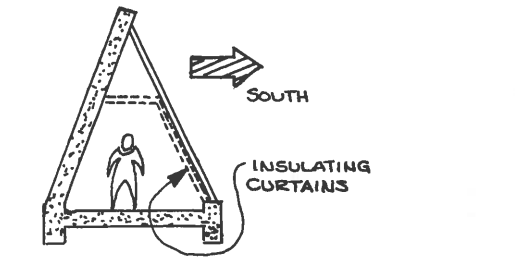
Vertical North Wall

- It never casts a shadow on the solarium at latitude 45°, except very early and very late in the day in the summer.
- It provides an ideal, interior location for a solar collector for domestic hot water.
- It does not reduce floor space inside the solarium.



Steeply Inclined North Wall

- If it is inclined towards the south at an angle equal to the solar altitude at noon on 21 June, then the north wall will never cast a shadow on the solarium except very early and very late in the day in the summer.
- It reflects winter sun down onto the solarium floor.
- It reduces the usable floor space inside the solarium, compared to a vertical wall on the same foundation.
- In the design of the structure it may be difficult to avoid horizontal or diagonal ties across the solarium space at inconvenient heights.



Gently Inclined North Roof

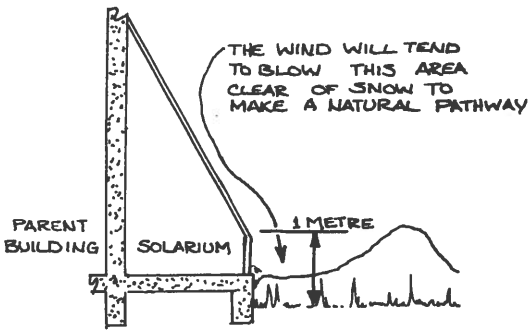
- It will cast a shadow over much of the solarium during the summer. This will help prevent overheating, but it may also inhibit the growth of plants in the shaded area.
- It is a convenient solution for solaria which are to be built on a south-facing slope, as indicated by the dotted line.
- In the design of the structure it may be difficult to avoid horizontal ties at inconvenient heights.

A-Frame Configuration

- The structure can be more economical because of the symmetry.
- In order to provide adequate floor area, a high space is required. If the solarium is to be kept warm at night, it is important to install the insulating curtains in such a way that the volume of air to be heated can be reduced.

The Need for a Knee Wall

Even if the glazing inclination chosen is a steep slope, such as 60°, it is wise to provide a knee wall at the low end of the glazed surface. The knee wall can be glazed or unglazed, as suits the design. It will prevent the accumulation of snow at the base of the solarium; otherwise the snow would climb up the slope and cast shadows inside the solarium.



East and West Wall Glazing

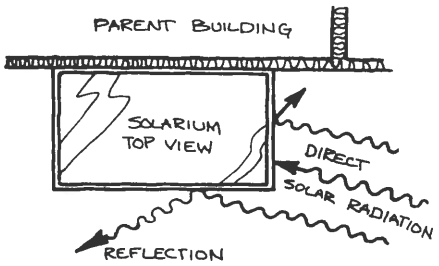
If the end walls of your solarium will face east and west, you may be tempted to glaze these as well. However, direct solar radiation on east and west surfaces, at the beginning and end of the day, is usually so weak that glazed end walls lose more heat than they gain.

A detailed calculation of the heat gained and lost through the end walls can be made using information in the next chapter. However, you may decide to ignore heat-loss factors and glaze end walls in any case, to provide a view, or to increase plant productivity.

If this is your decision, insulating curtains are recommended since they can be left closed in very bad weather. You might also consider insulating panels which are installed on the end walls during the winter, but removed for the summer.

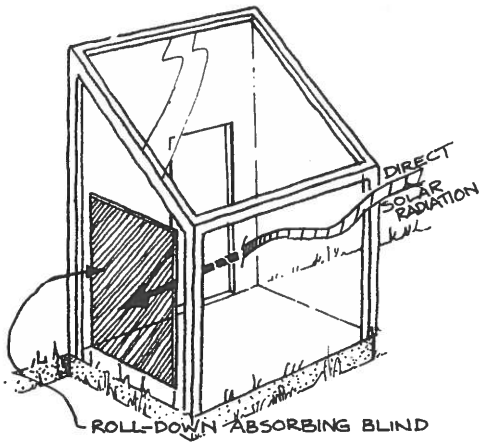
If the solarium is not very long in relation to its width, much of the radiation may pass right through it and out the other side if the end walls are glazed. This may be avoided by:

- changing the configuration so the solarium is longer in relation to its width. Losses will still occur through the end walls, but they will be proportionately smaller;
- constructing the end walls of opaque materials rather than of glazing;
- using removable insulating curtains or absorbing blinds which can be pulled down in front of the inside face of the side-wall glazing to block the exit of radiation.



Material Preferences

Both practical and aesthetic points of view come into play here. Choose materials which you know how to use and repair easily if you will be the builder. Consider the ability of the material to age gracefully, and the amount of maintenance it will need over the years. Also be sure to consider how well the materials of your new solarium will blend with those of the existing building.



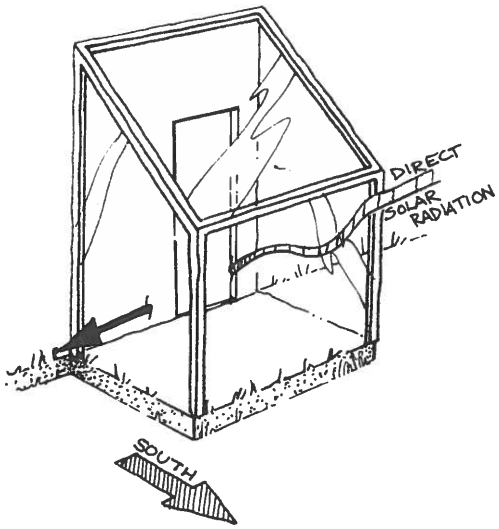
Preliminary Design Example

The example chosen is a typical farmhouse, two storeys high, with a verandah along the east-facing wall of the house. The farmhouse is located near Montreal so that environmental data for that city can be used.

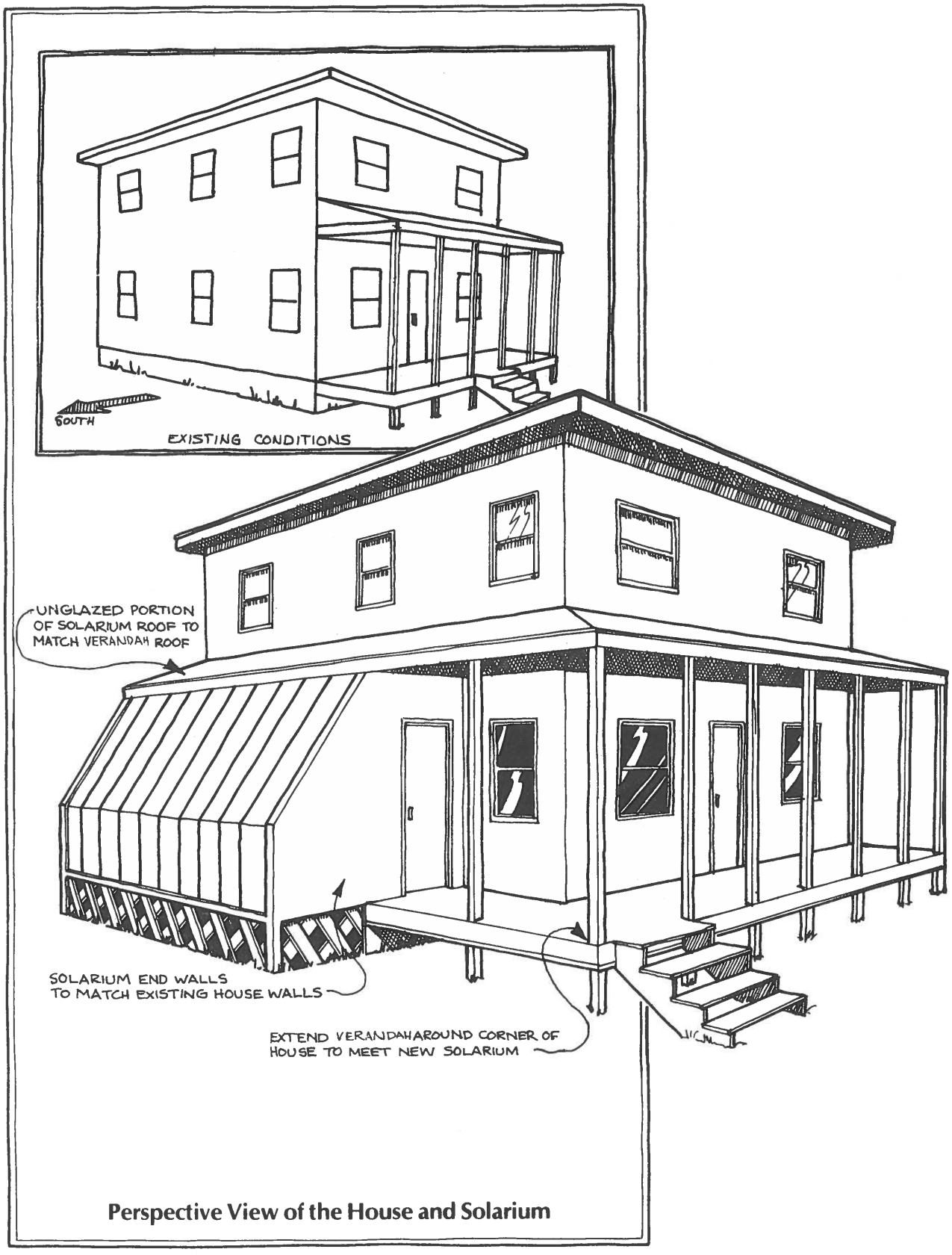
The owner has decided the solarium will be located along the south-facing wall of the house. It is to be incorporated into a new porch which will extend along the length of the south wall and meet up with the existing one. The verandah roof overhang will be the upper starting point of the glazed structure. The kitchen door will also be relocated to gain direct access to the solarium from the house.

The type of sketches required to describe a preliminary design are shown on the following pages. The sketches, however, do not constitute a complete package, but they are sufficient to illustrate the design process. Your drawing package should include the following:

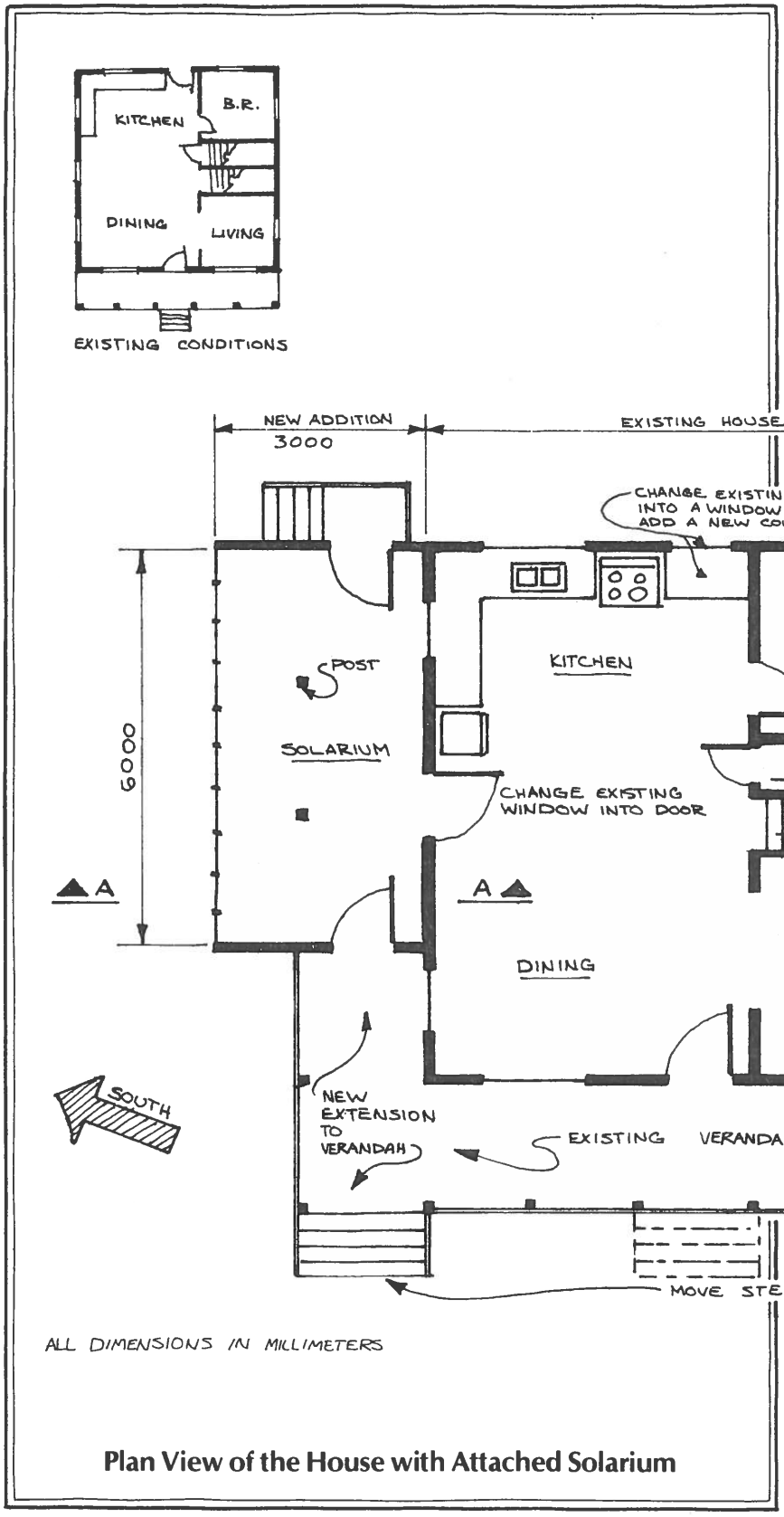
- one site plan, showing property lines, buried telephone cables, power lines, water supply, sewers, etc.;
- one floor plan, to scale, with the main solarium dimensions and general notes concerning modifications to the parent building;
- perspective drawings of the installation, showing the solarium from all directions (usually two sketches will be sufficient);
- one cross-section of the solarium, showing foundations, main structure, location of insulation, glazing, etc.



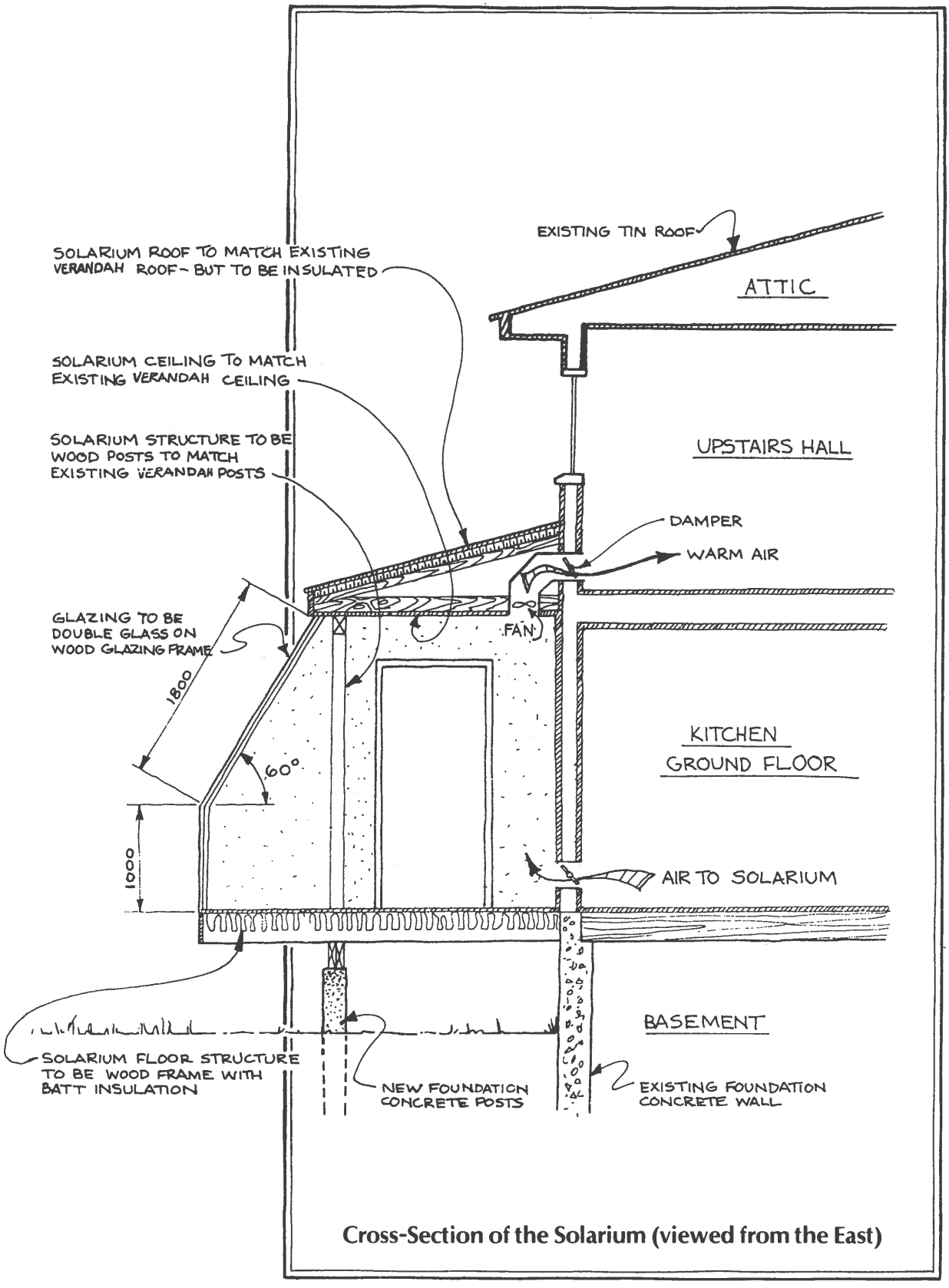
The performance of the preliminary design is evaluated in Chapter 4. The calculations cover energy performance, preliminary cost estimates and a cost-benefit analysis.


SOUTH
EXISTING CONDITIONS
UNGLAZED PORTION OF SOLARIUM ROOF TO MATCH VERANDAH ROOF
SOLARIUM END WALLS TO MATCH EXISTING HOUSE WALLS
EXTEND VERANDAH AROUND CORNER OF HOUSE TO MEET NEW SOLARIUM

Perspective View of the House and Solarium



Plan View of the House with Attached Solarium



Cross-Section of the Solarium (viewed from the East)

CHAPTER 4
EVALUATION OF THE PRELIMINARY DESIGN

A procedure for determining the effectiveness of the solarium as a heat producer is presented below. The technical assumptions made to facilitate the work are explained immediately while the economic framework is considered later with the discussion of the cost analysis work sheet.

Technical Assumptions

Four basic assumptions have been made in this book to allow simple performance calculations. First, the solarium is well situated and designed to absorb the solar energy. Second, the solarium has little thermal mass so that most of the solar-generated heat can be transferred by ventilation to the main building. Third, the parent building can effectively use all the heat supplied to it during the heating season. Fourth, the insulating value of the solarium to the parent building is not very significant.

Conditions for making the first assumption valid are simple; the design is such that the sun does not shine in through one glazing and directly out another, and the absorbing surfaces are just that, absorbing and not too reflective. The solarium is situated such that it is not shaded to any great extent through the heating season. A few deciduous trees can be tolerated south of the solarium as the shading due to the leaves would principally be in summer.

The second assumption is valid for a simple uncluttered woodframe design; it is not appropriate for a greenhouse with the thermal mass of the humid soil and the large amount of heat being used for evaporation.

The third assumption is very difficult to deal with by simple rules of thumb. The assumption will be best approximated when:

a) The contribution of the solarium is only a small part of the total heating load of the building for any given month.
b) Heat is distributed evenly throughout the house, for instance, by leaving the fan of the forced air heating system in operation during the day.
c) Thermal mass such as brick or masonry walls are within the building.
d) The south-facing window area of the main building is not substantial.
e) The temperature swing from cool at night to warm in the day that one is willing to tolerate is high.

If conditions a, b and d are met then little concern need be given to the thermal mass. Under these conditions the solarium will provide heating during the daytime with negligible influence during the night. However, as one tries to provide more of the heating load extending into the evening hours the thermal mass must be much more substantial.

In a typical woodframe construction in Canada there is little thermal mass and overheating can quickly become a problem. The Division of Building Research of NRC analysed one such house and found that, for an accepted temperature swing of 21 to 27°C with an increase of 4.1 to 5.0 m^2 of south-facing window, only about one-third of the net heat gain through the additional 0.9 m^2 window surface could be effectively used. Obviously trying to meet a substantial portion of the heating load of a building should not be attempted in any passive solar construction without a very serious consideration of thermal mass.

Reference to this study is made in DBR Paper No. 944, Solar Heat Gains Through Windows in Canada, by S.A. Baraket.

The modest insulating value that the solarium provides to the parent building is not taken into account simply because there are much simpler ways of providing effective insulation if this is the main concern to the homeowner.

It should also be noted that the calculations are based on monthly averages of the ambient air temperature and solar radiation data. On any particular day the solarium may perform substantially better or worse than this average, depending upon the cloud cover and temperature.

Solarium Performance Calculations

The calculations have been arranged in a clear, step-by-step manner so they can be done by anyone with an interest in the subject. While all the calculations are simple, you may find a hand calculator to be very useful.

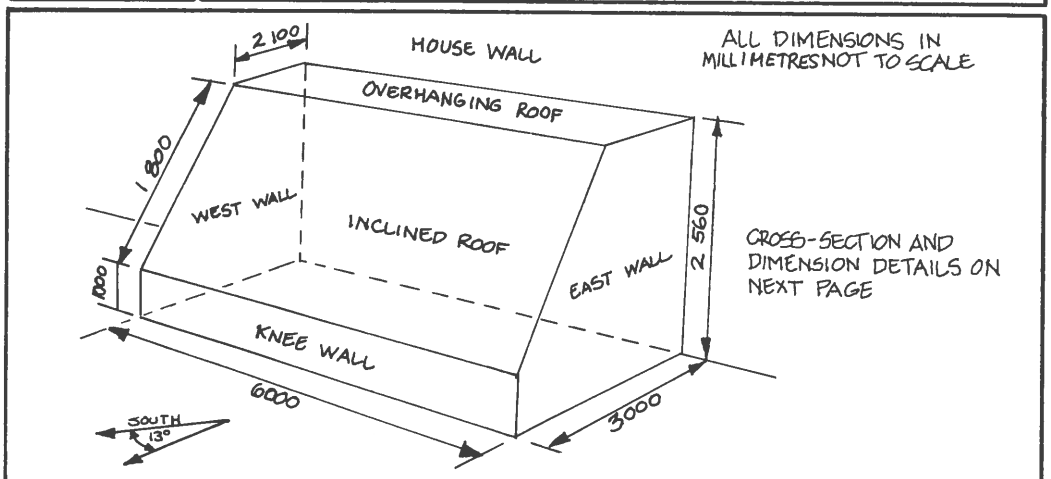
Blank worksheets numbered W1 to W9 are provided at the back of this workbook for your own calculations. An example, set in Montreal, has already been worked out. You should find it useful to go through this example first to get a clear understanding of the process before starting on your own. Every reference to the Montreal example is written in italics and is presented in the margin. The completed example worksheets are included with the instructions.

Also at the back of the workbook are appendices numbered A-1 to A-64 which contain solar, economic, and other information required to carry out the performance calculations.

Step-by-step instructions are given on how to use the worksheets for the calculations. The main step is written in bold type with further instructions and explanations written in a lighter typeface. The text in italics refers specifically to the Montreal example.

A homeowner in Montreal decided the ideal site for his solarium would be along the south facing wall of his house. The solarium will be incorporated into a new porch which will extend along the length of the south wall, and the roof overhang will be the upper starting point of the structure. The preliminary design example of Chapter 3 depicts this scheme. He has chosen double pane glass as glazing for aesthetic reasons. He will personally undertake all aspects of design and construction except those that legally require qualified personnel.

W1 General Specifications



Three-dimensional sketch of preliminary solarium design - Use extra sheets as required.

Volume of Solarium = area of cross section × length of solarium = _____ × _____ = _____ m^3

Col. 1 Elements of the Solarium Envelope	Col. 2 Construction of Each Element	Col. 3 Surface Area *A* (m^2)	Col. 4 Heat Transfer Coefficient *U* ($W/m^2 \cdot °C$) (A-1 to A-11)	Col. 5 Glazing Factor *gf*	Col. 6 Orientation (Degrees from due south)	Col. 7 Inclination (glazing only) (degrees from horizontal)	Col. 8 Transmittance of Solar Radiation *tr* (A-12, A-13)
INCLINED ROOF	DOUBLE GLASS GLAZING	10.80	3.30	0.87	13	60	0.71
KNEE WALL	DOUBLE GLASS GLAZING	6.00	3.30	0.83	13	90	0.71
WEST WALL	INSULATED (90 mm batts)	6.98	0.50	—	—	—	—
EAST WALL	INSULATED (90 mm batts)	6.98	0.50	—	—	—	—
FLOOR	INSULATED (200 mm batts)	18.00	0.24	—	—	—	—
OVER-HANGING ROOF	INSULATED (200 mm batts)	13.80	0.23	—	—	—	—

Worksheet 1 (W1) General Specifications

Box 1

☐ **Draw a three dimensional sketch of your solarium.**

Include all the outside dimensions on it and preferably draw to scale. Draw an end view (cross-section) on the second page and list all design constraints (e.g., height restrictions).

Line 1

☐ **Calculate the volume of the solarium (in cubic metres).**

This is done by calculating the area of the cross-section and multiplying it by the length of the solarium.

Col. 1

☐ **Write down the elements of the solarium envelope.**

The Montreal example has fairly typical solarium elements: over-hanging roof, east wall and west wall, inclined roof, knee wall and floor.

Col. 2

☐ **List the construction method of each of the elements.**

This is not as difficult as it sounds. Just write in whether the glazing will be single or double and whether or not the walls will be insulated.

Col. 3

☐ **Calculate the surface area, *A*, (in square metres) for each of the elements.**

Calculate the area from your dimensioned drawings.

Surface area = length × width

From the dimensions given on the scale drawings, the surface area of the inclined roof is:

$$A = \frac{6000}{1000} \times \frac{1800}{1000} = 10.80 \text{ m}^2$$

Col. 4

☐ **Record the heat-transfer coefficient *U* for each element.**

The *U* value (or heat-transfer coefficient) for a material is the rate at which heat is allowed to pass through that material, and is measured in watts per square metre per degree Celsius.

The *R* value is the overall thermal resistance. This is simply the reciprocal of the *U* value: $R = 1/U$. *R* values are expressed in metre-degree Celsius per watt. The higher the *R* value, the lower the heat loss. Technically speaking, the *R* value as defined above should not be confused with the well known *R* value associated with home insulation, because the latter does not include inside/outside air-film coefficients.

***The panes of the double glazing are each 5 mm thick with an air space of 13 mm between them. According to Table A-1, the U value is* 3.3.**

To find the *U* value for the glazed surfaces of the solarium, turn to Table A-1 at the back of this workbook. Here you will see a list of common glazing materials. If you don't know exactly what thickness to use, have a look at the *U* values. Remember, the *U* value stands for the rate that heat will pass through the material, so the higher the number, the faster the escape of heat. Therefore, pick a low *U* value if possible.

To find the *U* values for the solid or non-glazed areas of the solarium, you will be using Tables A-2 to A-11. Be prepared! There are a lot of them; but they are not difficult. Simply flip through the tables until you find the description that best represents the construction method that you plan to use in your solarium.

Walls – wood frame – A-2 to A-4
Walls – concrete or masonry – A-5 to A-7
Roof – wood frame – A-8 to A-10
Floor – A-11.

Again, if you have not decided on the construction method, examine the *U* values given in the tables and select a suitable method.

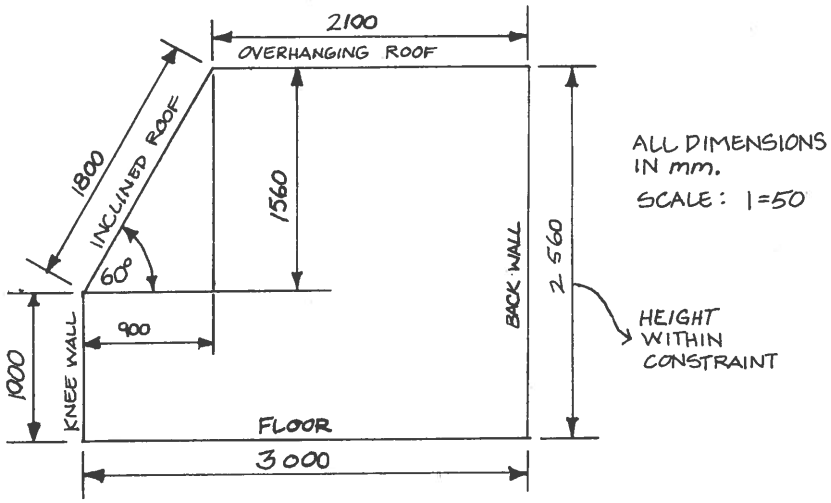
W1 General Specifications

REFERENCE DIMENSIONS: OVERHANGING ROOF = 2100 mm.
ASSUMED DIMENSIONS: FLOOR WIDTH = 3000 mm.
KNEE WALL = 1000 mm.
GLAZING INCLINATION = 60° (INCLINED ROOF) 30° (KNEE WALL)
CONSTRAINT: HEIGHT TO BE LESS THAN 3100 mm.

DRAWING TO SCALE GIVES THE FINALIZED DIMENSIONS AS SHOWN BELOW IN THE DIAGRAM

$$\text{CROSS SECTIONAL AREA} = \frac{\left(\left(\frac{1}{2} \times 900 \times 1560\right) + (1560 \times 2100) + (1000 \times 3000)\right)}{(1000)^2}$$

$$= 6.98\ m^2$$



CROSS SECTION OF SOLARIUM

Col. 5

☐ **Calculate the glazing factor, *gf*.**

The glazing factor, *gf*, of a solarium face refers to the proportion of actual glazing surface to the total surface area of the glazed face. It is defined here as the glazed area divided by the total surface area of that face:

$$gf = \frac{\text{glazed area of solarium face}}{\text{total area of solarium face}}$$

A glazing factor must be calculated for each face of the solarium which has glazing.

When the sun's radiation is not normal to the surface, the glazing factor decreases. However, the decrease will not be significant if:
- the glazing factor calculated at normal incidence is high;
- the glazing is not recessed far below its support frame.

Col. 6

☐ **Determine the orientation of each glazed face.**

To find the exact orientation of your solarium, it may be useful to get an accurate surveyed map from City Hall. You want to find out exactly how many degrees away from due south the solarium faces.

Col. 7

☐ **Calculate the angle of inclination (from horizontal) of each glazed face.**

Use a protractor on your cross section drawing to measure this angle. (Make sure your drawing is to scale!) Repeat for each glazed face.

Col. 8

☐ **Calculate the tansmittance of solar radiation, *tr*, for each glazed element.**

Table A-12 gives the average weighted daily transmittance values, *tr*, for single pane glass as a function of inclination and orientation of the glazed surface.

The table on A-13 gives the multiplication factors for different glazings. If your glazing is anything other than single pane glass, the net transmittance will be the product of the transmittance for single pane glass times the multiplication factor.

tr = transmittance for single pane glass × multiplication factor

It is assumed that the glazing is supported every meter by a 75 mm thick glazing frame. The shading factor of the glazed inclined roof is therefore:

Glazed area is:

$$6 \times \left(\frac{925}{1000} \times \frac{1700}{1000}\right) = 9.44 \text{ m}^2$$

Total area is **10.80 m²** ***as calculated above.***

Therefore,

$gf = 10.80 - 9.44 = 0.87$

This means that when the solar radiation is normal to the glazed face, 87% of it will strike the glazed surface and 13% will strike the structure.

The owner determined the orientation of the house's "south" wall to be actually 13° west of due south. This is also the orientation of the solarium's glazed face. The east and west walls are insulated so that their orientation need not be recorded.

Both the inclined roof and the knee wall are to be glazed. The inclination of the knee wall is 90° and that of the inclined roof is 60°.

From Table A-12, using a glazing orientation of 15° from due south and an inclination of 60°, the transmittance of single pane glass on the inclined roof is **0.82.** ***Referring to Table A-13, the multiplication factor for double pane glass (5mm thick) is*** **0.87.** ***Therefore, the actual transmittance of the glazed inclined roof will be:***

$tr = 0.82 \times 0.87 = 0.71$

W2 Calculation of the Average Daily Solar Heat Gain, Q, for Each Month

Glazed Elements of the Solarium Envelope

	1. INCLINED ROOF	2. KNEE WALL	3.	4.
A =	10.80 m²	6.00 m²		
gf =	0.87	0.83		
tr =	0.71	0.71		
$(A \times gf \times tr)$ =	6.67	3.54		

Surface Area (from W1 Col. 3)
Glazing Factor (from W1 Col. 5)
Transmittance (from W1 Col. 8)
Orientation (from W1 Col. 6)
Inclination (from W1 Col. 7)
see A-14 to A-41
13°
60°
90°

$\frac{1}{1000} \times$ 6.67 $= q$ | $\frac{1}{1000} \times$ 3.54 $= q$ | $\frac{1}{1000} \times$ _____ $= q$ | $\frac{1}{1000} \times$ _____ $= q$

	$\left(\frac{kW \cdot h}{m^2 \cdot d}\right)$ (m²) $\left(\frac{kW \cdot h}{d}\right)$				$\left(\frac{kW \cdot h}{m^2 \cdot d}\right)$ (m²) $\left(\frac{kW \cdot h}{d}\right)$			$\left(\frac{kW \cdot h}{m^2 \cdot d}\right)$ (m²) $\left(\frac{kW \cdot h}{d}\right)$			$\left(\frac{kW \cdot h}{m^2 \cdot d}\right)$ (m²) $\left(\frac{kW \cdot h}{d}\right)$			Col. 4 Total Average Daily Gross Solar Heat Gain to Solarium Through all Glazed Panel Q (kW·h/d)
	Col. 1	Col. 2	Col. 3		Col. 1	Col. 2	Col. 3	Col. 1	Col. 2	Col. 3	Col. 1	Col. 2	Col. 3	
January	2,701	6.67	18.0		2501	3.54	8.9							26.9
February	3689	6.67	24.6		3210	3.54	11.4							36.0
March	4,092	6.67			3,235	3.54	11.5							38.8
April	4,096	6.67			2,923	3.54	10.3							37.6
May														
June														
July														
August														
September														
October	3,015	6.67			2,520	3.54	8.9							29.0
November	1,912	6.67			1,708	3.54	6.0							18.8
December	1,914	6.67			1,781	3.54	6.3							19.1

Worksheet 2 (W2) Calculation of the Average Daily Solar Heat Gain, Q, for Each Month

Copy the details from Worksheet 1 including A, gf and tr for each glazed element.

Col. 1

☐ **Calculate the average daily solar radiation incident on glazed surfaces, I, for each month.**

The tables from A-14 to A-41 give the solar radiation values I for 14 Canadian cities. This should serve the majority of Canadians; however, if you have any doubts concerning the applicability of the data, you should contact theAtmospheric and Environmental Services, Canadian Climate Centre, Downsview, Ontario.

For each city, orientation (east and west from due south) and inclination (off horizontal) are given in degrees in increments of 15° from 0° to 90°. You should use the orientation which is closet to your own particular case. Should your orientation or inclination fall equally between those listed, a simple proporation between values is accurate enough.

You already know the inclination and orientation of the glazed elements (from W1, Cols. 6 and 7), so with this information you can find the average daily solar radiation from the appropriate chart.

Given the inclination of 60° and orientation of 15° of the inclined roof, the incident radiation can be found on Table A-30. For the month of January, there will be an average of* 2701 W·h/(m² · d) *incident on the inclined roof.

Col. 2

☐ **Calculate the factor $A \times gf \times tr$ for each element.**

The factor ($A \times gh \times tr$) is a constant for each glazed element of the solarium envelope and can be calculated separately. Write this result in column 2 for each element.

From the example of the inclined roof again, the gross solar heat gain in January will be:

$$A \times gf \times tr = 10.80 \times 0.87 \times 0.71$$
$$= 6.67 \text{ m}^2$$
$$q = 6.67 \times \frac{1}{1000}$$
$$= 6.67 \times \frac{2701}{1000}$$
$$= 18.0 \text{ kW·h/d}$$

Col. 3

☐ **Calculate the average daily gross solar heat gain q through each glazed element of the solarium for each month.**

This is the heat gained by the glazed element assuming there are no heat losses (these will be determined later).

$$q = (A \times gf \times tr) \times I$$

where: q = *gross solar heat gain for the glazed element*
A = *surface area of the glazed element (from W1 Col. 3)*
gf = *glazing factor (from W1 Col. 5)*
tr = *transmittance (from W1 Col. 8)*
I = *average daily solar radiation (from W2 Col. 1)*

Repeat this calculation for each glazed element.

Note: June to September should be excluded as the non-heating months of the year. Although May is a heating month it too should probably not be considered. The May solar gains will be high relative to the heating needs of the house but the assumption made earlier that this solar gain will be entirely useful to fill these needs is not well justified in the late spring. The cold temperatures will be mainly during rainy weather or at night. Solar gains through the windows of the house itself will almost surely meet the heating needs when the solarium could be a heat source in May.

For the month of January, the total gross solar heat gain Q will be the sum of the heat gains calculated for each glazed element for that month:

Q = *q inclined roof* + *q knee wall*
= 18.0 + 8.9
= 26.9 kW·h/d

Col. 4

☐ **Calculate the total average daily gross solar heat gain Q.**

Add all the q values together for each month (i.e, the sum of the values in no. 3 column).

W3 Calculation of the Heat Loss Coefficient for the Solarium

Elements of the Solarium Envelope	While no insulating covers are being used to protect the glazing from heat loss: U (from W1 Col. 4) (W/(m²·°C))	× A (from W1 Col. 3) (m²)	= UA Col. 1 (W/°C)	While insulating covers are being used to protect the glazing from heat loss*: $U_{combined}$ (see text) (W/(m²·°C))	× A (from W1 Col. 3) (m²)	= UA Col. 2 (W/°C)
INCLINED ROOF	3.30	10.80	35.64			
KNEE WALL	3.30	6.00	19.80			
WEST WALL	0.50	6.98	3.49			
EAST WALL	0.50	6.98	3.49			
FLOOR	0.24	18.00	4.32			
OVERHANGING ROOF	0.23	13.80	3.17			

		Col. 1	Col. 2
Line 1	Sum of the UA values for all the elements of the solarium envelope. Sub-Total	69.91	Sub-Total
Line 2	If the solarium floor has *not* been included in the list of elements above, then floor losses may be approximated by: Line 1 × 0.10 = × 0.10	N/A	Repeat the same figure for uninsulated floor losses
Line 3	Heat Loss Due to Air Infiltration (volume × 0.335 W/(m³ · °C))	14.03	Repeat the same figure for air infiltration losses
Line 4	Overall heat loss coefficient for the Solarium (sum lines 1, 2 and 3) UA1	83.94	Overall heat loss coefficient UA2

*If the solarium is to have insulating curtains, it is necessary to calculate two overall *UA* values:
UA 1 while the insulating curtains are open, leaving the glazing exposed;
UA 2 while the insulating curtains are closed, protecting the glazing from heat loss.
*Note that the value of *U* will remain unchanged from the value established in W1 for the non-glazed elements, or for glazed elements without insulating covers.

Worksheet 3 (W3) Calculation of the Overall Heat-Loss Coefficient for the Solarium

Col. 1 or 2

☐ **Calculate the heat-loss coefficient, *UA*, for each element.**

After re-copying the elements, their U value and their surface areas from W1, multiply the U value by the surface area ($U \times A$) for each of the solarium elements. (In this text, this product will be referred to as the UA value.) If you are not using insulating covers, write this result in column 1. If insulation covers are used to protect the glazing from heat loss, look up the U value of the cover in A-2 to A-11 (or of a construction similar to the cover). The inverse of the combined heat-transfer coefficient for the protected glazed element is calculated by adding together the inverses of the U values for the cover and for the glazed element. Thus:

$$\frac{1}{U_{\text{combined}}} = \frac{1}{U_{\text{glazing}}} + \frac{1}{U_{\text{cover}}}$$

or

$$U_{\text{combined}} = \frac{U_{\text{glazing}} \cdot U_{\text{cover}}}{U_{\text{glazing}} + U_{\text{cover}}}$$

The overall heat-loss coefficient is then the product of the combined U value and the surface area of the element. Write this result in Col. 2.

Line 1

☐ **Calculate the subtotal of the *UA* values**

Line 2

☐ **Calculate the *UA* value of the floor (if uninsulated)**

If your floor is uninsulated, (i.e., a patio floor), estimate its UA value by taking 10% of the subtotal (line 1). If it is insulated, it should be included as an element of the solarium envelope.

Line 3

☐ **Calculate the heat loss due to air infiltration**

This is calculated approximately by multiplying the volume of the solarium by 0.335 W/(m³ · °C).

Line 4

☐ **Calculate the total overall heat-loss coefficient**

This is done by adding up the UA values of each element (line 1), the coefficient of the uninsulated floor (line 2), and the heat loss due to air infiltration. This will give the total overall heat-loss coefficient for the solarium in watts per degree Celsius.

W4 Calculation of the Average Daily Heat Loss, L, from the Solarium for Each Month

	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6
	Average Inside Operating Temperature t_i (°C)	Average Outside Ambient Temperature t_o (°C)	Losses While Solarium is Operating During Hours of Daylight (from W3 Line 4)(see A-43 to A-48) $(t_i - t_o)$ (°C)	× $UA1$ (kW/°C)	× Duration (h/d)	= Losses (kW·h/d)
January	21	-9	30	83.94	6	15.1
February	21	-7	28	83.94	8	18.8
March	21	-2	23	83.94	8	15.4
April	21	5	16	83.94	9	12.1
May						
June						
July						
August						
September						
October	21	8	13	83.94	8	8.7
November	21	1	20	83.94	7	11.8
December	21	-6	27	83.94	6	13.6

Worksheet 4 (W4) Calculation of the Average Daily Heat Loss, L, From the Solarium for Each Month

Col. 1

☐ **Decide on an average inside operating temperature, t_i.**

This is the temperature, t_i, at which you would like to keep your house all year round.

The owner used 21°C which is fairly standard and which you might like to use too.

Col. 2

☐ **Find the average outside ambient temperature *to* for each month.**

The average monthly temperatures t_o for 14 Canadian cities can be found on Table A-42.

Col. 3

☐ **Calculate the difference between the inside and outside temperatures for each month ($t_i - t_o$).**

Col. 4

☐ **Recopy the total heat-loss coefficient for the solarium (from W3 line 4).**

Col. 5

☐ **Calculate the duration of the solarium operation.**

This is essentially governed by the user. A rational approach would be to use the solarium when the sun shines, and to either close it off at other times or to use insulating covers.

The owner decided against insulating covers and will use the solarium only very occasionally when the auxiliary heater will be needed. For the remainder of the time, the solarium will be shut off from the house.

Tables A-43 to A-48 will help you to determine the average length of day (number of daylight hours), or more correctly, the total possible number of sunshine hours in each month. This value is not only dependent on the time of year, but also on the orientation and inclination of the glazed surface. The sun can be considered to have risen on a surface only when direct solar radiation is incident upon that surface, which is not necessarily when one can see it is daylight. For example, the sun will rise around noon for a vertical surface oriented 90° west of due south. Consequently, the tables list the possible number of sunshine hours for the given 14 locations as related to geometry of the glazed surface.

In January, the total possible number of sunshine hours is eight for both the knee wall and the inclined roof (from Table A-43).

Keep in mind also that when the sun is just rising or setting the useful solar radiation on a glazed surface is small. This is caused by its large angle of incidence relative to the glazing, and therefore the large reflection losses. For calculation purposes, it is better to subtract one hour after sunrise and one hour before sunset from the total number of sunshine hours.

The time duration of an average January day should be reduced by two hours to account for reflectance losses at sunrise and sunset. Therefore the solarium, will be considered operating six hours per day.

Note: If a solarium is designed to operate strictly on a daylight-hours basis, and if there are glazing faces having different sunshine hours (e.g., glazed end walls), then use the largest glazed area to calculate the duration of solarium operation.

Col. 6

☐ **Calculate the daily heat loss from the solarium for each month.**

This is done by multiplying together columns 3, 4 and 5. Repeat for each month.

Box 2

☐ **Calculate the losses while the solarium is operating during hours of darkness with insulated covers.**

Note: If you are only using the solarium during the day and closing it down during the night, do not complete this step, go on to column 11.

☐ **Col. 7** is a repeat of Col. 3.

W4 Calculation of the Average Daily Heat Loss, L, from the Solarium for Each Month

	Col. 7	Col. 8	Col. 9	Col. 10	Col.11
	Losses While Solarium is Operating During Hours of Darkness				Total Average Daily Heat Losses (Col. 6 + Col 10) L (kW·h/d)
	(Repeat Col. 3) $(t_i - t_o)$ (°C) ×	$UA2$ (kW/°C) ×	Duration (h/d) =	Losses (kW·h/d)	
January		N/A		N/A	15.1
February					18.8
March					15.4
April					12.1
May					
June					
July					
August					
September					
October					8.7
November		↓		↓	11.8
December		N/A		N/A	13.6

☐ **Col. 8** is the heat-loss coefficient if insulated covers are used — *UA2* (from W3 line 4)

☐ **Col. 9** is the duration of the use of night covers. This would be 24 h minus the total number of sunshine hours (from Tables A-43 to A-48).

☐ **Col. 10** is the place to multiply the values of columns 7, 8, and 9 to calculate the heat losses while the solarium is operating during the hours of darkness.

Col. 11

☐ **Calculate the total average daily heat loss *L*, from the solarium for each month.**

This is done by adding together the values from Col. 6 and Col. 10. Repeat for each month.

This worksheet allows for some flexibility in calculating heat losses because, in practice, they will depend very much on the way in which the solarium is used. For example, you may wish to keep the solarium open as a family room for a few hours after sunset, without using opaque insulating covers. This should be taken into account in the determination of duration times in the daily heat loss calculations. In this case, you may wish to have the solarium "operating" from 9:00 to 22:00, so that the duration would be 13 h in the heat loss calculations, with the solarium closed off for the rest of the night. Any change in the operating schedule of the solarium from that originally planned will, therefore, affect the performance calculations.

W5 Calculation of the Net Monthly Heat Gain, H, and Equivalent Fuel Units, F, Produced Monthly

	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8
	Q (kW·h/d) (from W2 Col. 4)	L (kW·h/d) (from W4 Col. 11)	$Q - L$ (kW·h/d)	n (d)	H (kW·h)	Cf (kW·h/L) (see A-49)	Ce (see A-49)	F (L)
January	26.9	15.1	11.8	31	366	10.74	0.65	52
February	36.0	18.8	17.2	28	482	10.74	0.65	69
March	38.8	15.4	23.4	31	725	10.74	0.65	104
April	37.6	12.1	25.5	30	765	10.74	0.65	110
May				31				
June				30				
July				31				
August				31				
September				30				
October	29.0	8.7	20.3	31	629	10.74	0.65	90
November	18.8	11.8	7.0	30	210	10.74	0.65	30
December	19.1	13.6	5.5	31	171	10.74	0.65	24

Worksheet 5 (W5) Calculation of the Net Monthly Heat Gain, H, and the Equivalent Fuel Units, F, Produced Monthly

Col. 1 and 2

☐ **Record the monthly values of the average daily gross heat gain Q and average daily heat loss, L.**

The gross heat gain, Q, is from W2 C 4 and the average daily heat loss L is from W4 Col. 1.

Col. 3

☐ **Calculate the net average daily heat gain $(Q - L)$.**

This is done by simply subtracting the daily heat loss L from the gross daily heat gain Q.

Col. 5

☐ **Calculate the net monthly heat gain H.**

This can be determined from the following formula:

$H = (Q - L) \times n$

where: H = net monthly heat gain

$(Q - L)$ = net average daily heat gain for each month (Col. 3)

n = number of days in the month (Col. 4)

Col. 6

☐ **Record the value of the equivalent fuel conversion factor Cf.**

Simply read the value of the fuel conversion factor, Cf, on Table A-49 corresponding to the type of time-heating energy which you are using, or plan to use, in the parent building. Make a note of the units you are using directly on the worksheet to avoid confusion later on.

Col. 7

☐ **Record the value of the fuel conversion efficiency, Ce.**

Again, simply read the value of the fuel conversion efficiency, Ce, on Table A-49 for the type of home-heating energy you are using. This factor adjusts the calculated fuel saving arising from the solarium operation to take into account the efficiency of the heating system it partially replaces.

Col. 8

☐ **Calculate the equivalent fuel units, F, produced monthly.**

The net monthly heat gain, H, can also be expressed as a fuel equivalent, F, determined with the following equation.

$$F = \frac{H}{Cf \times Ce}$$

Where Cf and Ce are from columns 6 and 7, respectively.

The heat gain H for January is:

$$H = (Q - L) \times N$$
$$= (26.9 - 15.1) \times 31$$
$$= 366 \text{ kW·h}$$

The parent building heating system uses # 2 fuel oil. The fuel conversion factor Cf is 10 741 W.h/L *and the conversion efficiency Ce is* 0.65. *The fuel equivalent F for the month of January is:*

$$F = \frac{H}{Cf \times Ce}$$
$$= \frac{366}{10.74 \times 0.65}$$
$$= 52\text{L}$$

Therefore, this solarium design would effectively reduce the fuel consumption of the parent building by 52 L *during the month of January taking the furnace efficiency into account.*

W6 Calculation of the Net Equivalent Fuel Saving, S, and Dollar Value, V, During the First Year of Operation

	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5
	Average Monthly Fuel Requirement for Space Heating (personal records) *M* in LITRES (inscribe units)	Equivalent Fuel Units Produced Monthly by the Solarium (from W5 Col. 10) *F* in LITRES (inscribe units)	Net Equivalent Monthly Fuel Saving *Sm* in LITRES (inscribe units)	Estimated Unit Cost of Fuel During the First Year of Operation ($/unit)	Dollar Value of *Sm:* *Vm* $
January	366	52	52	0.22	11.44
February	348	69	69	0.22	15.18
March	296	104	104	0.22	22.88
April	172	110	110	0.22	24.20
May					
June					
July					
August					
September					
October	132	90	90	0.22	19.80
November	222	30	30	0.22	6.60
December	352	24	24	0.22	5.28

Box 1 S = 479 L — The Total Annual Net Equivalent Fuel Saving

Box 2 V = $ 105 — Total Dollar Value of the Net Equivalent Fuel Saving

Worksheet 6 (W6) Calculation of the Net Equivalent Fuel Saving, S, and Dollar Value, V, During the First Year of Operation.

In W5 you calculated the equivalent number of fuel units produced by the solarium; however, this is not necessarily the fuel saving, since it is possible for a solarium to produce more heat than the parent building requires. This situation can occur at the beginning and at the end of the heating season when incident radiation is high and heat losses are reduced because of warmer outside temperatures.

Col. 1

☐ **Calculate your fuel consumption per month,** M.

This can be calculated from your personal fuel records.

Col. 2

☐ **Recopy the,** F**, values from W5 Col. 8.**

Col. 3

☐ **Calculate the net monthly saving** Sm.

If M is greater than F, then $Sm = F$;
If M is less than F, then $Sm = M$.
In the latter case, the extra heat produced by the solarium must be vented to the outside.

The homeowner estimated the cost of # 2 fuel oil to be 22 ¢/L for the first year.

Col. 4

☐ **Estimate the unit cost of fuel during the first year of operation.**

This can be calculated from your personal records.

Col. 5

☐ **Calculate the dollar value,** Vm**, of the monthly fuel saving.**

Multiply the net monthy saving, Sm, by the estimated unit cost of fuel to get the dollar value, Vm.

$Vm = Sm \times$ cost of fuel
This calculation is repeated for each month.

Box 1

☐ **Calculate the annual net equivalent fuel saving,** S.

The annual saving is the sum of the monthly fuel savings (Col. 3).

Box 2

☐ **Calculate the dollar value,** V**, of the net equivalent fuel savings during the first year of operation.**

The dollar value for the first year is the sum of the monthly dollar values (Col. 5).

The total annnual net equivalent fuel saving works out to 479 L of # 2 fuel oil which has a dollar value of $105 for the first year of operation.

W7 Calculation of the Operating Cost of the Solarium in the First Year of Operation

Col. 1 Description of Equipment	Col. 2 Equipment Power Rating (1 hp = 0.7457 kW) (1000 W = 1 kW)	Col. 3 Operating Time per Year (h)	Col. 4 Electrical Power Requirement (kW·h) (Col. 2 × Col. 3)	Col. 5 Operating Cost (Col.4 × $/kWh)
AIR MOVING FAN	20 W	952	19.0	0.76
AUXILIARY HEATER	1.5 kW	20	30	1.20
			Total	$ 2

Worksheet 7 (W7) Calculation of the Operating Cost, *OC*, of the Solarium for the First Year of Operation.

The operating cost of the solarium will be that associated with the use of active air-distribution systems, auxiliary heating, lighting, etc., as they apply to your particular design. Such systems are designed specifically for each application and there are no simple rules of thumb. If your design utilizes these systems, refer to Chapter 6 to estimate your power requirements. The solarium operating cost is calculated using Worksheet 7.

Col. 1

☐ **List electrically powered equipment.**

This list should include all electrical equipment, such as lights, fans, etc.

Col. 2

☐ **List the equipment power ratings.**

Electrical appliances are usually fitted with description plates giving their power rating in watts (W) or kilowatts (kW).

If the power rating is given as a horsepower (hp), as for a fan motor, this value is transformed into electrical power units (kilowatts or kW) by multiplying hp by the constant 0.7457:

$$kW = hp \times 0.7457$$

Using the procedure given in Chapter 6, the owner calculated that the two fans should be eight watts each. He found two rated at ten watts.

Col. 3

☐ **Determine the equipment operating time per year.**

Equipment actual operating time depends on many factors, such as the heat-loss coefficient of the solarium, its thermal mass, weather conditions, etc. At the design stage, some simple assumptions can be made to arrive at reasonable estimates.

It can be assumed that an air-circulation fan will be operating during bright sunshine hours when the solarium has excess heat. Use Table A-50 to determine the number of bright sunshine hours for each month of the heating season and total these to get the operating time per year.

In this case, the solarium would be used from October to May inclusive. From Table A-50, the total number of bright sunshine hours for that period, and hence the air circulation fan operating time, is **952 h.**

If the solarium is to be left open to the parent building at night, you should have calculated a daily heat loss on W4. This is equal to the daily heating-load requirement on the parent-building heating system. The monthly heating load will be the product of the daily load multiplied by the number of days per month for each month of the heating season. The cost of this extra heating load can be calculated with the information given in W5 and W6 and entered as an operating cost in this column (on a yearly basis).

Other equipment operating times, such as lighting are probably best evaluated on a daily basis multiplied by the number of days for each heating month.

The heating and lighting of the solarium will only be very occasional with the air circulation fan being used much more frequently. The annual electrical requirement for that solarium would then be:

Col. 4

☐ **Calculate the yearly electrical power requirement.**

This is obtained by multiplying together the values in columns 2 and 3.

$$\textit{Annual Energy Requirement} = \textit{Power of fan} \times \textit{hours used} + \textit{Power of heater} \times \textit{hours used}$$

$$= \frac{20}{1000}\,\text{kW} \times 952\,\text{h} + 1.5\,\text{kW} \times 20\text{h}$$

$$= 49\,\text{kW.h}$$

W8 Preliminary Estimate of Construction Cost

Solarium Element	Description and Notes	Quantity	Unit Cost ($) see (A-53 to A-55)	Total Cost ($)
Demolition	WALL OPENINGS FOR AIR DISTRIBUTION, CHANGE WINDOW TO A DOOR		DIY	
Foundations	CONCRETE POSTS 1220 m.m. O.C.	8	22 each	176
Exterior Walls (not glazed)	INSULATING PANELING FIBERGLASS BATTS	15.4 m^2	30/m^2	462
Roof (not glazed)	PANELING, BATT INSULATION AND SHINGLES	12.6 m^2	17/m^2	214
Floor	WOOD FLOOR, JOISTS, INSULATION	18.0 m^2	33/m^2	594
Interior Partitions	NONE			
Doors	WOOD DOOR, FRAME AND HARDWARE	2	140 each	280
Standard Windows	RELOCATE ONE WINDOW		DIY	
Glazing and Glazing Frames	THERMAL PANE, WITH FRAME	16.8 m^2	97/m^2	1630
Insulating Curtains	NOT USED			
Ventilation and Heat Distribution	2 FANS, DAMPERS AND THERMOSTAT	425 m^3	5/m^3	213
Heating	AUXILIARY ELECTRIC BASEBOARD HEATER (1.5kW) + OUTLET	1	90 each	90
Electrical	1 SWITCH, 2 OUTLETS	3	25 each	75
Plumbing	NONE			
			Sub-Total	3734
			Add 15% of sub-total for miscellaneous	560
			Total	4294
For do-it-yourself construction, the contingency can be reduced or even eliminated			Add 25% of total for contingencies	
			Estimated Cost	4294

Col. 5

☐ **Calculate the first year operating cost,** *OC*.

The first year operating cost of each piece of equipment is obtained by multiplying the yearly power requirement (Col. 4 in kW · h) by your electricity rate in dollars per kilowatt hour. The total operating cost is the sum of the equipment operating costs.

The owner calculated the cost of his electricity to be **$0.04 per kW·h** *using past Hydro-Quebec bills. Therefore:*

Operating Cost:
$OC = 49.0 \times 0.04 = \$2$

(This operating cost is very low, but the owner is also fully aware of how fast the cost would increase with more frequent use of the auxiliary heater).

Worksheet 8 (W8) Preliminary Estimate of Construction Cost

Worksheets 1 through 7 have been primarily concerned with energy. Those considerations led you to select construction methods and materials whose costs must not be estimated to establish economic performance and feasibility. At this preliminary design stage, a good approximation is all that is required.

A reasonable estimate can be made by dividing the solarium design into its basic elements i.e., walls, floor, roof and glazed surfaces. Estimate the cost of each element separately using the average construction costs given in Tables A-51 to A-53 and add these values to arrive at the total cost. This method will help you assess which elements of your solarium are the most expensive and where you should put the most attention if you want to reduce the initital cost.

Remember to include in your estimate the costs of the auxiliary equipment such as electrical fixtures, air-moving devices (if used), auxiliary heating systems, plumbing (e.g., drainage), doors, etc., as these items can make up a significant portion of the total cost.

You can use Worksheet 8 for your estimate.

The homeowner calculated the cost of the solarium elements to be **$4 294,** *including a 15% contingency to cover breakage, wastage and unforeseen miscellaneous expenses.*

W9 Life-Cycle Cost Analysis

Economic Parameters

Line 1 General Inflation Rate (% per annum) _____ i = 10

Line 2 Escalation Rate of the Cost of Non-Solar Energy: oil, gas, electricity (% per annum) _____ e = 16

Line 3 Discount Rate on Investments (% per annum) _____ d = 12

Line 4 Mortgage Interest Rate (% per annum) _____ i = NA

Term of the Mortgage (years) _____ t = NA

Line 5 Life-Cycle Period (years) _____ N = 20

Life-Cycle Expenses (*LCE*)

Cost Factor	Type of Expenses ($)		Present Value Multiplier	Present Value ($)
	Fixed Amount	First Year Payments		
Initial Cost	4294			4294
Operating Cost		2	25.44	51
Maintenance Repairs and Insurance		72	15.13	1089
Property Tax		144	15.13	2179
			LCE Total	$ 7613

Life-Cycle Benefits (*LCB*)

Saving Factor	Type of Benefits ($)		Present Value Multiplier	Present Value ($)
	Fixed Amount	First Year Benefits		
Fuel Savings		105	25.44	2671
Resale Value	7200		0.697	5018
			LCB Total	$ 7689

Present Value of Life-Cycle Solar Savings (*LCSS*)

LCSS = *LCB* − *LCE* = $ 7689 − $ 7613 = $ 76

Worksheet 9 (W9) Life Cycle Cost Analysis

This analysis is aimed at estimating the overall economic costs and benefits of a solarium. Its use can help you identify clearly the most significant economic factors affecting your design choices. This, in turn, can lead to an optimizing process where different approaches are rated to determine the most appropriate for you.

Cost Factors

The main factors involved in the costing of solaria are the following:

- initial cost of the installation, including the cost of necessary repairs to the parent building;
- down payment and terms of the mortgage (interest rate and repayment schedule);
- operating costs;
- maintenance, repairs and insurance costs;
- property taxes;
- value of the solarium at the end of the period of analysis;
- general rate of inflation;
- solar energy savings;
- escalation rate of the cost of non-solar energy (oil, gas, electricity);
- the rate of return expected on your alternative investment opportunities;
- possible tax rebates and other forms of government-incentive programs in favour of solar equipment procurement.

These factors must be analyzed in such a way as to reflect costs and benefits over the lifetime of the system. This is especially true when you wish to compare a solar system with a conventional home-heating system. The solar system has a high initial cost and low operating and maintenance cost, whereas the conventional system has a more moderate initial cost but higher operating costs because of its fuel needs. One method of analysis which does allow an effective comparison between these alternatives is life-cycle costing.

Life-Cycle Costing and the Concept of Present Value

The principal feature of life-cycle costing is that all costs and benefits are appropriately weighted to reflect their present value; these present values then provide a common basis to permit summing of all items to yield a net present value for the system. The weighting function is a compound interest formula based upon the rate of return which you can get on your investment opportunities. In this text, this rate of return will be referred to as your discount rate. The choice and use of your discount rate is explained in the next paragraphs.

The basic question to be answered is the following: What present value do you give to a payment to be made to you some time in the future, say $1 000, in one year's time? With general inflation at approximately 10% per annum, its value would surely be a fair amount less, but specifically how much less?

If you just wanted to have the same buying power, the present value of $1 000 would be $1 000/1.10 = $909.09. But if you had some money immediately available for investment you could probably get a higher rate of return than that. For instance, you may find bonds at 13%. In this case, $1 000/1.13 = $884.96. To invest in these bonds would represent the same value to you now as that $1 000 one year in the future.

If this sum were to be paid two years in the future the present value would be $\$1\,000/1.13^2 = \$783.15$. This is the well-known compound-interest calculation. That interest rate which you use to discount future costs and benefits to their present value is your discount rate.

The choice of your discount rate will play a very important role in your analysis. Rates lower than the general inflation rate would be unusual, as this means that you are accepting an effective decrease in your buying power. These low rates may be appropriate, however, if your investment possibilities are subject to high tax rates. If your discount rate is considerably higher than the inflation rate (say 5% higher), then you are admitting that money presently available to you is much more valuable than future payments either because of high interest rates associated with loans you must make, or because alternative investment possibilities will bring in substantial returns.

You must be careful, however, to take into consideration the effect of taxes. For instance, if you have a 13% bond, but you are taxed at 40% on that interest, then your effective rate of return is only 7.8%. Your discount rate should reflect your real possible rate of return rather than the nominal 13%.

Life-cycle costing, as the name suggests, usually extends over the lifetime of a system. For a solarium this may be for periods too long to make any reasonable estimates of the different interest rates. Therefore, you should probably restrict your analysis to 20 years and account for any further future returns by giving a re-sale value to the solarium at the end of that period.

Now all you need to complete an analysis is a number of formulae to apply to the different forms that future payments can take. These forms are enumerated below with examples applicable to a solarium study. A more complete review of the subject is in Building Research Note No. 150, *Life Cycle Cost Equations*, by R.K. Beach. The tables of Appendix A are based on the equations presented in this note.

Single-Payment Factor — *SPF*

The single-payment factor is used to calculate the present value of a future payment whose amount is known. The single-payment factor is a function of your discount rate, d, and of the number of years, N, until the payment is made or received. Values of *SPF* are tabulated on page A-56.

If you were to make a $1 000 purchase in five years time, say, to outfit your solarium with insulating blinds, you can calculate the amount of money, *PV*, that should be invested today at your estimated rate of return, say 12%, to cover that future expense:

$$\begin{aligned} PV &= 1\,000 \times SPF\,(12\%, 5 \text{ years}) \\ &= \$1\,000 \times 0.567 \\ &= \$\ \ 567 \end{aligned}$$

Single Payment Factor with Escalation — *SPFE*

Now consider the case of a future payment whose amount you can evaluate today, but which is escalating over time at an annual rate e. The future amount F is calculated by multiplying the current amount P by the factor $(1 + e)^N$ — this is the simple compound interest formula. The present value of that future payment is calculated by applying the single-payment factor to the escalated price *FV*. Values of *SPFE* are tabulated on pages A-57 to A-59.

Certain plastic glazings have limited lives because the ultra violet radiation from the sun degrades the material. Thus, you may be looking at the replacement of the glazing after, say, 20 years. Assuming that the cost today is $800, that it will escalate at a general inflation rate of 10% per annum, and that your discount rate is 12%, the present value, *PV*, of that future payment is:

PV = \$800 × *SPFE* (10% *e*; 12% *d*; 20 years)
= \$800 × 0.697
= \$558.00

Multiple-Payment Factor — *MPF*

The present value of a series of regular payments whose amount is not changing over time is calculated using the multiple-payment factor. The multiple-payment factor is simply the sum of the single-payment factors over N years. Values of *MPF* are tabulated on page A-60.

The multiple-payment factor can be used to calculate the present value of regular mortgage payments. If you were to borrow say \$5 000 at 13%, to be repaid in monthly installments over five years (60 months), each installment would be approximately \$130. The present value of these mortgage payments will be determined by your alternative investment opportunities over that period of time. Thus if you could get 12% annually on the sum of these installments, the present value, PV, of the payments will be:

PV = \$(130 × 12) × *MPF* (12%, 5 years)
= \$1 560 × 3.605
= \$5 624

Multiple-Payment Factor with Escalation — *MPFE*

This factor will let you calculate the present value of multiple payments whose amount is escalating over time. This factor is in effect the sum of the single-payment factors with escalation e taken into account over N years. Values of *MPFE* are tabulated on pages A-61 to A-63.

The *MPFE* can be used to calculate the present value of the fuel savings. Assume savings of \$100 per year whose value is escalating at 14% per year, and assume your discount rate to be 12%. Over a 20 year life-cycle period, the present value of the savings is given by:

PV = \$100 × *MPFE* (14% *e*; 12% *d*; 20 years)
= \$100 × 21.237
= \$2 124

Life-Cycle Costing Calculations

Lines 1 to 5

☐ **Determine and record the basic parameters of your analysis.**

Based on your own experience and knowledge, determine reasonable values for inflation, price escalation of non-solar energy, your discount rate, and your mortgage interest rate (if you are borrowing money to finance this project). Here are two examples of scenarios that you may want to adopt.

Item	Optimistic (%)	Pessimistic (%)
Inflation	8	12
Escalation — oil	12	18
— gas	12	18
— electricity*	8	14
Discount rate (personal)	16	8
Mortgage interest (personal)	10	18

**The price of electricity varies greatly from province to province, and so does the price escalation rate.*

Going back to the Montreal example, the homeowner has decided to use the following economic parameters:
General inflation i = 10%
Escalation rate for non-solar energy e = 16%
Discount rate d = 12%
Life cycle period N = 20 yrs.

The homeowner has decided to finance the solarium with personal savings so that the present value of the initial cost is the initial cost itself, **$4 294.**

Line 6

☐ **Determine the present value of the solarium initial cost.**

The initial cost of the solarium was calculated on W8. It can be financed entirely from out-of-pocket money, or a mortgage can be contracted, with or without an initial down payment.

If the solarium is paid for in cash, the present value of the initial cost is equal to the initial cost itself.

If the solarium initial cost is to be financed by a mortgage, there will be a financial cost associated with it if the mortgage interest rate is greater than your discount rate. Conversely, it would be beneficial to finance the solarium with a mortgage at an interest rate lower than your discount rate, since the investment would cover the mortgage payments and still leave money to spare. In most cases however, the mortgage interest rate will be close to your rate of return, so that the present value of mortgage payments will be equal to the amount of the mortgage, i.e., the initial cost of the solarium.

Therefore, unless your rate of return is different from your mortgage interest rate, the present value of the solarium initial cost will be that calculated on W8.

In this example, the operating cost is very small, **$2** *per year. From Table A-62, the present worth multiplier MPFE is* **25.436** *for the selected values of the eonomic parameters and the present value of the operating costs over 20 years is* **$51.** *(The escalation rate for electricity should probably be 12% or 14% rather than the 16% used here.)*

Line 7

☐ **Calculate the present value of the operating costs.**

The operating costs calculated on W7 can be expected to escalate over the life-cycle period. Be careful to use the escalation rate corresponding to the type of energy used, because the cost of electricity probably doesn't increase as rapidly as the cost of oil and gas. The present value of the operating costs, *OC*, is given by:

$PVOC = OC \times MPFE$

where: *MPFE* is from Tables A-61 to A-63 corresponding to N, e and d defined above.
OC is the operating cost from W7.

Line 8

☐ **Calculate the present value of the maintenance, repairs and insurance costs.**

General maintenance, occasional repairs, and insurance costs can all be expected to increase at the general rate of inflation over the life-cycle period. It will be assumed here that insurance, normal maintenance and small occasional repairs require a combined annual investment of 1% of the building's value. The present value of the maintenance cost, *MC*, is given by:

$PVMC = (1/100) \times IV \times MPFE$

where: *MPFE* is from Tables A-61 to A-63 corresponding to N, i and d defined above;
IV is the initial value.

The homeowner has made a very summary estimate of the real value of his solarium from Table 3-2. It might be classed at the lower end of what a general contractor would do, so based upon a floor area of **18 m²** *and a cost of* **400 $/m²** *he arrives at* **18 m² X 400 $/m² = $7 200.**

For a solarium built by a general contractor the initial value should be fairly close to the initial cost. However, if you are a competent do-it-yourselfer, then the initial value may be considerably more than your costs. The value of labour put into the construction is significant as can be seen from the Preliminary Cost Estimate Data. This data may be used to calculate the initial value or you may arrive at a rough estimate based upon Table 3-2. Eventually your tax assessor will help you in this matter.

The total of the maintenance, repairs and insurance costs amounts to **$72.** *From Table A-62, MPFE is* **15.13** *and the present value of these costs over the life-cycle period is* **$1 089.**

If you are anticipating the need for a major repair or upgrading in a certain number of years, the present value of this cost can be calculated knowing what the cost of this work would be today. Multiply this current cost by the appropriate single payment factor, *SPF*, as shown in the introduction to life-cycle costing above.

Line 9

☐ **Calculate the present value of property taxes.**

The annual property tax associated with the solarium over and above that of the house usually represents around 2% of its value, but you should verify this with your municipality. The amount of property tax paid can be expected to increase at the general inflation rate. The present value of the annual tax payments is given by:

$PVPT = (2/100) \times IV \times MPFE$

where the terms are as defined above.

The property tax will be about 2% of the assessed real value, the first year payment will be **$144.** *The MPFE is again equal to* **15.13** *and the present value of the annual tax payments is* **$2 179.**

Line 10

☐ **Calculate the present value of the life-cycle expenses,** *LCE*.

This is simply the sum of the present values of the life-cycle expenses.

In this example, the present value of the life-cycle expenses is **$7 613.**

Line 11

☐ **Calculate the present value of the fuel savings.**

The dollar value of the fuel savings, V, for the first year of operation was calculated on W6. It is expected that the dollar amount of these savings will increase over the life-cycle period at an annual escalation rate, e, corresponding to the type of non-solar home-heating energy you are or will be using. The present value of these savings is given by:

$PVV = V \times MPFE$

where the terms are as defined above.

The dollar value of the fuel savings in the first year amounts to **$105** *and the present worth multiplier (from Table A-62) MPFE is* **25.44** *the 16% cost escalation rate selected. Therefore the present value of the 20 year savings is* **$2 671.**

Line 12

☐ **Calculate the present value of the solarium resale value at the end of the life-cycle period.**

Over the last 20 years the cost of housing has risen steadily, reflecting the general inflation rate plus net cost increases in many regions of the country. It can safely be assumed that this trend will continue over the next 20 years.

For life-cycle periods up to 20 years, the resale value of a solarium should not diminish substantially, especially if the maintenance and repair is ensured. Therefore the present value of the resale value can be calculated from the initial value, escalating that at the general rate of inflation and discounting it at your discount rate. Of course, in practice, this resale value will depend on many factors including your neighbourhood and the condition of the parent building.

One major assumption made in this calculation is that we are referring to an energy-efficient solarium. Just as people are becoming reluctant to buy gas-guzzling cars, they are becoming increasingly aware of the importance of low fuel consumption for their homes. The solarium which is a big fuel consumer rather than a saver will be obsolete and its resale value will reflect this.

The present value of the solarium resale price, RP, based on the initial value, IV, is given by:

$PVRP = IV \times SPFE$

for a 20-year life-cycle.

From the tables of the single payment factor with escalation the present value of the resale price (for $i = 10\%$, $d = 12\%$, $N = 20$ *years) is* **$7 200 × 0.697 = $5 018.**

Line 13

☐ **Calculate the present value of the life-cycle benefits,** *LCB*.

This is done by simply adding up the present values of the benefits calculated on lines 11 and 12.

Note: in the case of a greenhouse, the value of the fuel savings may be negligible or non-existent; (there may actually be a net heating cost involved. In this case, the savings resulting from growing food should be included as a life-cycle benefit. It can be handled in the same manner as

The life-cycle economic benefits for this solarium total **$7 689.** *Again it is stressed that the energy-efficient design has played an important role, not only in the fuel savings but in the resale value.*

In this example the life-cycle savings are positive. In other words this project is economically very interesting to our homeowner. In all objectivity, this is in large part due to the labour which he was willing to contribute at no cost. Therefore many of you not having the time or interest to do this construction will end up with a negative net savings. However, this small cost of the solarium will probably be considered well warranted by the additional living space, and its impact on a better life-style. In many ways the solarium can make a lot of sense.

fuel savings, taking into account the annual price escalation rate for food and discounting the yearly savings to obtain a net present value.

Line 14

☐ **Calculate the present value of the life-cycle solar savings,** *LCSS*.
The present value of the life-cycle solar savings is given by the difference between the life-cycle benefits and the life-cycle expenses. A positive value of *LCSS* indicates a cost-effective project.

Uses of the Cost Analysis

By reducing all costs and benefits to their present value, life-cycle costing analysis gives a good indication of the relative significance of the many factors involved in the economic analysis of a particular design. Your efforts at reducing costs should first be directed at the higher cost items, working down to the smaller items. The methods of life-cycle costing will also help you evaluate the effects of cost reductions. For example, a reduction in the quality of construction materials will result in a reduced initial cost, but, also in a lower resale value; the analysis will show whether or not this is advantageous.

You can examine the effect of varying the glazing area on the life-cycle solar savings, because expenses and benefits do not necessarily change in the same proportion when the glazing area is changed. The increase in operating costs associated with a larger solarium may be more than compensated for by fuel savings. Of course, the size of the solarium will ultimately be determined by the site restrictions and the heating requirements of the parent building. You can also examine and compare the economic performance of different design concepts and thus determine the optimum concept for your site, if such options are open to you. The energy performance of the best concept can then be optimized using the methods described above.

Additional Factors in the Decision to Build

One effective incentive to building a solarium already in the federal income tax legislation should not be overlooked. Capital gains realized in the sale of your permanent dwelling are not taxable. Thus the added value of the solarium which is recuperated when selling the house is not subject to tax.

The decision to build a solarium should not be based solely on the results of the life-cycle costing analysis, since this only reflects financial considerations. Convenience, the luxury of a warm sunny space during the winter, and the availability of extra space are all important factors to consider in you decision making. Similarly, you may place greater value in the conservation of our scarce resources than the market prices for non-renewable energy would indicate. The economic analysis must be viewed mainly as a tool to evaluate and compare the relative merits of alternative designs within the given financial constraints.

When reviewing your life-cycle cost calculations it is important to get a clear understanding of the limitations of the analysis. This is best shown by calculating the life-cycle solar savings with two or three sets of basic parameters (inflation, discount rate, price escalation, mortgage terms, and life-cycle time period) to determine the sensitivity of the analysis to the different rates. In the evaluation of solar thermal systems, this is very important because of the long life-cycle periods involved and the reliance on long-term economic predictions.

Another consideration you may want to keep in mind is the value of the energy savings from the point of view of overall energy use. Many studies show that certain solar alternatives which are not financially feasible often show net gains when analysed on the basis of total energy use. Such analyses calculate the net total energy input to manufacture the raw materials, assemble components, and construct the proposed installation including shipping costs. These inputs are then related to the total energy savings, taking into account the overall efficiency of producing a unit of heat, from pumping of the raw petroleum to your home furnace efficiency.

In general, these analyses show that virtually all energy-conservation measures, such as triple glazing or very high insulation values, are worthwhile in the long run with regard to overall energy use. Alternatively, it could be said that the current prices for non-solar-energy sources do not lead to their optimum allocation in the economy since feasibility studies based on financial criteria alone do not lead to the same conclusions.

While still at the design stage, you will have to decide whether factors such as comfort and enjoyment justify additional expenses to extend the role of the solarium from a simple solar collector to a full-time living space or even to a greenhouse. Conversely, you may decide to restrict the use of the solarium to improve cost effectiveness.

The determination of feasibility is an important part of the trial-and-error design process. It indicates where improvements should first be made as well as whether or not the project is economically viable. Repeating the steps of design, estimation of performance and costing will result in a refinement and optimization of your original design concept. This, in effect, will minimize the cost within the constraints of your requirements and objectives.

CHAPTER 5
DESIGN BRIEF

When you have decided to go ahead with the solarium project, you should review your work to make sure all aspects of the solarium operation have been considered. The project must now be clearly defined in the form of a design brief which will be used as the basis for the development of the final design.

Through drawings and written instructions, the design brief must specify clearly the objectives of your project and the operating conditions and specific requirements to be imposed on the solarium and its components. The design brief should express intent without necessarily including technical details. It can be used as the basic document to obtain quotes from contractors. Refer now to the preliminary sketches and notes which you have prepared and use them to determine the major requirements and conditions. The list will effectively constitute the design brief.

Though the scope and detail may vary with each solarium, the following will serve as a checklist of the basic points covered in a design brief.

Principal Use

The principal use of your solarium will essentially determine its type as one of the three given earlier. The important differences in design considerations will affect many main features, like the amount of thermal mass within the solarium. Therefore the objectives you hope to meet with your solarium should be clearly stated.

Location and Orientation

The position and orientation of the solarium were generally established for the preliminary design. It is now necessary to fix the location of the solarium with respect to the parent building precisely. Accurate dimensions are now important so the elements can be designed to fit exactly. Sufficient detail of the existing building must be given as to where the solarium is to be installed, together with any other information relevant to elements that cannot easily be changed.

Size and Shape

The existing building and economic factors will affect the size of the solarium. You must also ensure its size is not so great as to inhibit its efficiency as an energy collector.

After determining size and shape, you can modify preliminary drawings to show final size and general layout of the proposed solarium. Since these drawings will serve as one of the basic documents of the design brief, they should be clear, with dimensions as accurate as possible.

Type of Construction and Materials

A general type of construction must now be established, determining the form of the structure, the type of glazing, floor, foundation, and so on. Requirements of strength and safety must always be satisfied, and these must be balanced against performance, appearance and cost.

Special Conditions and Features

The requirements for such special features as doors, windows, insulation, protective shading, power outlets, lights, heat storage, drainage and decor must be indicated.

Heat Distribution System

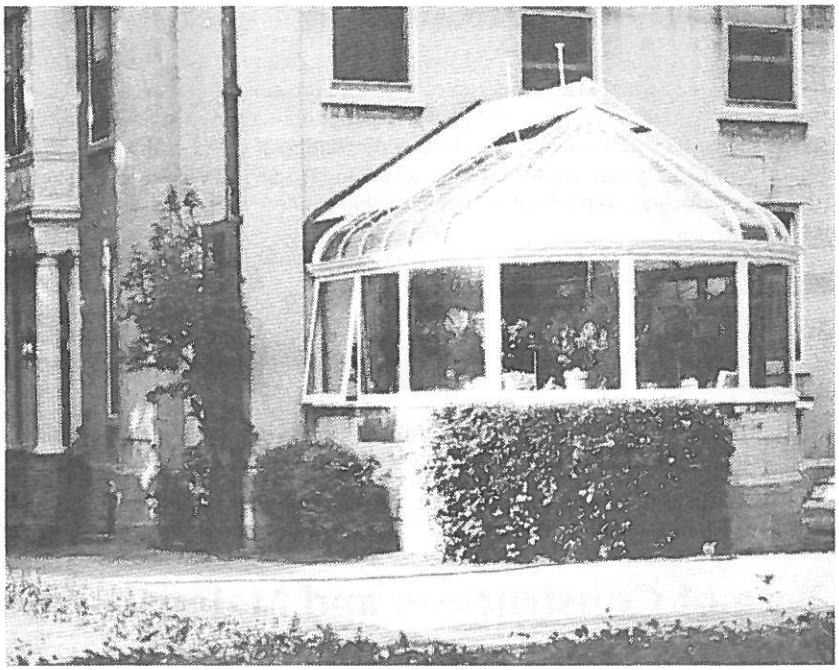
The proposed heat-distribution system must be outlined, including wall openings, dampers, ducts, diffusers, fans and controls, if required. Also describe the required ventilation. Although the details of these features may be beyond your technical capability, you must provide a general description of requirements.

Miscellaneous Effects

You may have to give some thought to local environmental effects, especially snow, ice and wind. While you might expect local contractors and suppliers to be familiar with local climatic conditions, it is still best to specify them. If you are considering using a glazing kit marketed on a national scale, it is very important to define carefully all unusual aspects of the site.

You must also consider the effect of snow loading on horizontal, or sloping surfaces. The closer the surface is to horizontal, the greater will be the snow load imposed.

Snow or ice falling from a roof can also be a hazard to glazing. Grating and other solutions to this problem are discussed in Chapter 6.



Note the use of grating to protect the glazing from falling ice and snow.

The effect of wind is very important for three reasons. First, it increases the scrubbing effect of air over the outer glazing, thereby increasing the heat transfer at the surface to the colder outside air. Secondly, wind imposes a direct load upon the structure and can actually loosen or blow away the glazing. Finally, the wind makes sealing against leaks more difficult.

In fact, if your site is subject to high winds, it may be necessary to plant or construct windbreaks. These should be located so as to minimize shading of the solarium during the winter. However, it should be noted that the force of the wind itself can always be used to contribute to better sealing of an opening. For example, the opening of a lap joint should always face away from the prevailing wind.

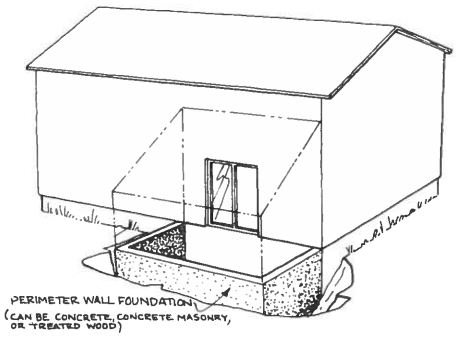
CHAPTER 6
DETAILED DESIGN

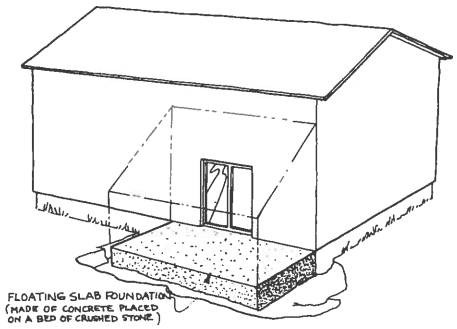
Repairs and Modifications to the Existing Building

When the design brief has been prepared, you must decide whether you can, or want to, develop the design yourself, or whether it should be done by an architect, engineer or contractor. The design of the solarium may then be developed to meet the requirements of the design brief and the budget.

If the new solarium is to be connected to, and supported by, parts of an existing building, you will first have ensured that all the structures involved are sound. A qualified person should then determine the best way of attaching such a solarium. The parent structure should also be in good enough repair to be worth the additional expense of the solarium.

If repairs are necessary, their timing should be given some thought. Repairs to the roof and chimney, for example, should be done before glazing is installed to avoid damage. However, work such as foundation repairs or structural work, can sometimes be advantageously carried out simultaneously with similar work on the solarium. Certain work, such as demolition of an existing verandah or shed, must be carried out without damaging the structural integrity of the building.
Note: It is very important the connections between the solarium and the parent building be properly sealed, allow for thermal expansion, and provide the necessary drainage and ventilation.





Foundations

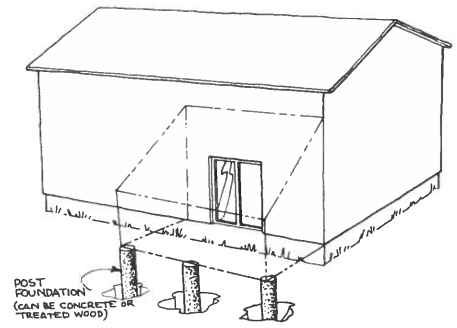
Solarium foundations need not be substantial to support the weight of what is usually a light structure. However, care must be taken to ensure there is minimal differential movement of its base as glazed structures are very susceptible to damage in this way.

Two important causes of foundation movement are settlement of the soil and frost heave. Settling of the soil occurs in the first few years after the construction of a house where the soil has been excavated and then backfilled. It can also occur through changes in the moisture content of clay soils. For instance, during a drought a tree's root system can seriously deplete the moisture about a foundation leading to substantial shrinkage and settlement (Building Research Note No. 100).

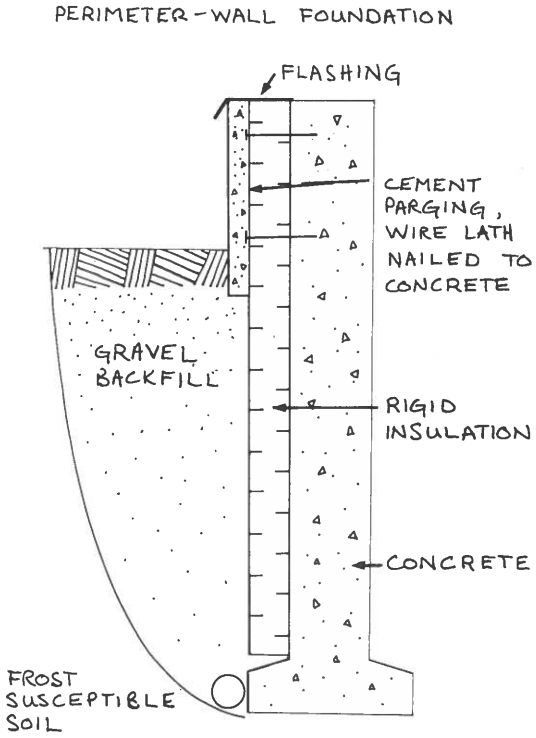
Frost heaving occurs in certain types of susceptible soils such as clays, silts and very fine-grained sand. As the soil freezes, moisture flows to the freezing front producing ice lenses which expand and can provoke very large heaving forces. To prevent this frost-heave damage to the foundation one can surround the foundation with less susceptible soils such as crushed rock and gravel and one can prevent freezing by insulating the exterior of the foundation.

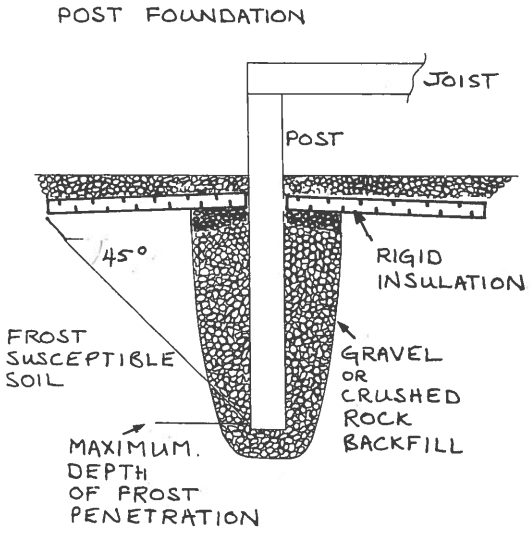
For the three basic types of foundation used for a solarium, the specific application of these two simple rules changes only slightly.

For a perimeter wall frost heave is avoided in susceptible soils by insulating the exterior of the foundation and by backfilling the excavation with gravel or coarse sand.



You should verify whether your soil is frost-susceptible by becoming informed of construction experience in your immediate area.





For a floating-slab foundation, the perimeter should again be insulated with some insulation extending out below grade from the perimeter (see the example of page 14). This type of foundation is most susceptible to differential settling as might occur beside a newly constructed house so that care should be taken to compact the base of the foundation, again with gravel or coarse sand.

For a post foundation in frost-susceptible soil the excavation should be extended and gravel used for backfill. The posts themselves are not insulated but rigid polystyrene can be extended horizontally just below the surface of the soil about the posts to prevent substantial soil freezing. In very frost problematic regions it may be necessary to anchor the post to a suitable footing below the maximum frost penetration depth (for more details, see Canadian Building Digest No. 128).

Your choice of a foundation type will be influenced by the cost and by the thermal mass requirements of your type of solarium.

The post foundation is inexpensive for non-frost-susceptible soils. It has the advantage for Type 1 and 3 solaria of introducing little thermal mass to the structure.

The floating slab provides a concrete floor which can be easily maintained whether it is painted directly or finished with tile. The thermal mass of the slab makes it advantageous for Type 2 solaria.

The perimeter wall allows one to use the excavated enclosed area either as extra space for the solarium or as an extension to the basement of the house. The concrete can provide thermal mass if desired for Type 2 solaria. The major disadvantage is the relatively high cost.

Structure

The structural frame, the glazing, and the glazing frame are three interrelated systems that must be designed to function together as a whole. Consequently, many of the principles discussed in the next section—glazing and glazing frames—apply to the structure as well.

The glazing frame and the structural frame can be two independent systems as illustrated in example 1.

The structural frame can also serve as the glazing frame, as in example 2. The glazing is fixed directly to the structural frame.

Climatic Requirements of the Structure

The components of the structure must be suitable for the Canadian climate with its wide range of temperatures, wind conditions, and precipitation. A solarium designed for a less vigorous climate may not be suitable for Canada. This applies to both individual components and to kits.

Snow Loading

Ideally, a solarium should be designed so snow will not accumulate on it—in other words, the roof angle should be greater than 45 degrees. The guidelines for sizing wood-frame structural members, given in *Canadian Wood Frame House Construction,* available from Canada Mortgage and Housing Corporation, account for the effect of inclination on wind and snow loads, and may therefore be applied to solarium applications.

If the presence of nearby buildings will cause snow to slide onto the solarium or to accumulate in unusually deep drifts against it, the structure must be designed to withstand the additional load. Further, if the configuration of the solarium and

the parent building is such that additional snow or ice may drop from some height, the structure must be designed to withstand the impact of the drop as well as the additional load. **In these cases, you should consult an architect or engineer.**

While snow may be brushed away from surfaces of small solaria, remember a heavy snowfall can occur when no one is present to remove the snow. Simply allowing the heat from the greenhouse-style solarium to melt accumulated snow is the technique used by many commercial greenhouse operators. However, this method consumes energy and is not, therefore, recommended.

Unglazed Structure

The structure for the floor and the unglazed sections of the wall and roof can be designed according to the standard construction practice described in *Canadian Wood Frame House Construction.*

In typical wall and roof construction, the structure is hidden between the exterior sheathing and the interior finish. The exterior finish protects it from the weather, and the interior finish protects it from the interior water vapour. Because this structure is not exposed to view, rough materials and imprecise workmanship are usually acceptable.

Glazed Structure

The structure for the glazed section of a solarium is more difficult to design. Because it is exposed, very careful design, quality materials and detailed workmanship are essential to prevent infiltration of weather and the exfiltration of water vapour. **Joints are particularly susceptible to damage from moisture.**

Structural Materials

The two most common materials used for the structure are aluminum and wood. Both have advantages and disadvantages. These are listed below:

Aluminum

Advantages:

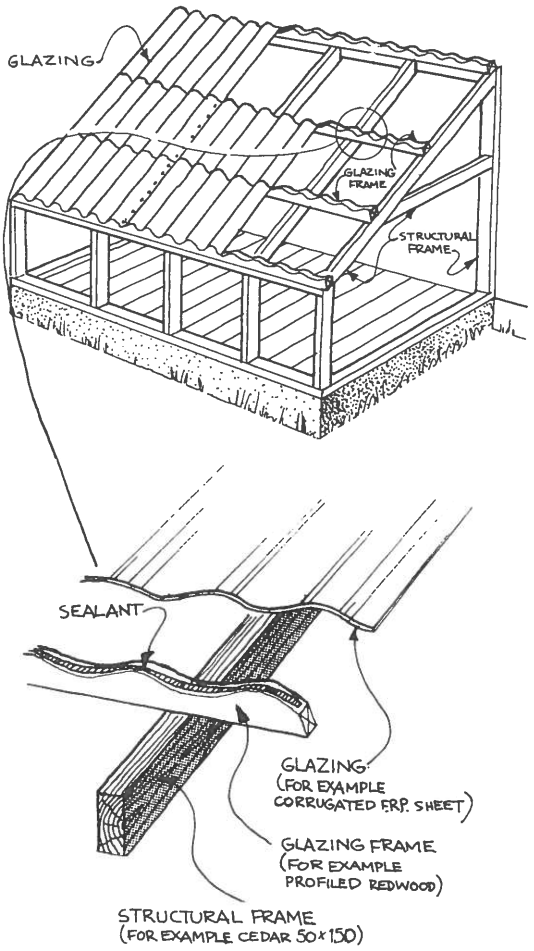
—An aluminum structure would normally be bought as a pre-engineered kit. You can provide the kit manufacturer with the preliminary design and require him to take responsibility for structural design to suit that configuration.
—Anodized aluminum will not be damaged by weathering or water vapour, provided the joints are well sealed.
—Aluminum structural members can usually be smaller than wood members, and therefore cause less interior shading.
—Aluminum requires very little maintenance.

Disadvantages:

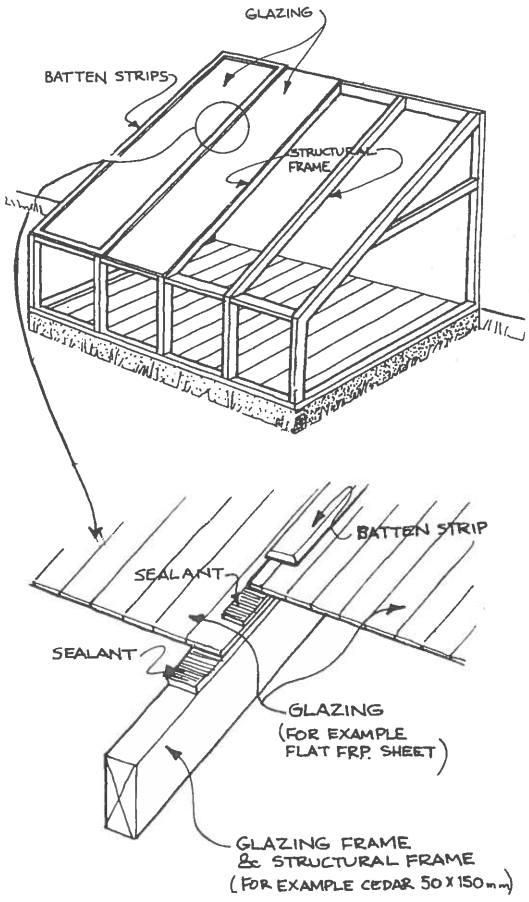
—It is expensive.
—Aluminum conducts heat easily. Therefore, the aluminum structural members must be isolated from the exterior to avoid excessive conductive heat losses and to prevent condensation. Many kits available do not adequately solve this problem.

Wood

Advantages
—In many places wood is more readily available and less expensive than aluminum.
—Most people have more experience working with wood than with aluminum and can easily design and fabricate their own wood components.
—Wood conducts heat much more slowly than aluminum.



Example 1



Example 2

Disadvantages:

—Because wood is porous, it continuously absorbs and releases moisture causing it alternately to swell and to shrink. This swelling and shrinking can warp the wood members and cause cracks to open up at joints.
—Wood will rot if exposed to moisture.

Designing a Structural Frame

The depth and width required for each structural member will depend upon the load it supports and its span (distance between its supports). If you have purchased a kit, you can expect it will be supplied with adequate structural members, provided you have supplied accurate information to the manufacturer. If you are designing your own wood structure, you can use the information given in such books as *Canadian Wood Frame House Construction.* On larger installations it may be wise to have the soundness of the structure verified by a structural engineer.

The structural frame, the glazing and the glazing frame are interrelated systems that must be designed simultaneously. Alternate materials for any one system must not be evaluated independently of the others.

Step 1: Establish the Live Load

Establish the load created by snow and wind—the live load—that will act upon the glazing materials. This will depend upon the configuration of the solarium and the local climatic conditions. Refer to the *National Building Code of Canada* and its supplements.

Step 2: Choose a Glazing Material

Make the final decision for the choice of glazing material. From the manufacturer's data, establish the intervals at which this particular glazing material must be supported. This distance is called the "maximum span" for the glazing.

Step 3: Choose a Glazing Frame

Choose the system to be used as a glazing frame that will support the glazing according to its maximum span.

From the properties of this glazing frame, establish the intervals at which it must be supported by the structural frame.

Step 4: Choose a Structural Frame

Choose the structural frame to support the glazing frame as required by its maximum span.

Glazing and Glazing Frames

A variety of glazing and glazing frame materials is currently available in the United States. The choice in most parts of Canada is more limited but hopefully it will expand as the solar energy industry develops. Because the industry is rapidly developing, products and materials are not discussed here. Instead, this section discusses the criteria for evaluating a glazing system for a solarium. It is left to you, the designer, to establish at the outset which criteria are most important for your solarium and on this basis, to compare the options available.

As you investigate the materials on the market, you will usually encounter conflicting information regarding their physical characteristics. It is advisable to take the following approach when examining a material.

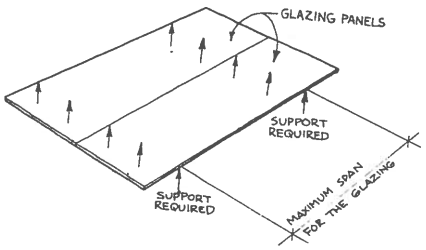
For technical characteristics which can be quantified (weight, thickness, transmissivity), the manufacturer's data should be the most reliable source, provided the characteristics were established according to standardized procedures. Usually this is stated along with the technical data. In many cases materials have been tested for exposure under severe climatic conditions. The designer should check these results.

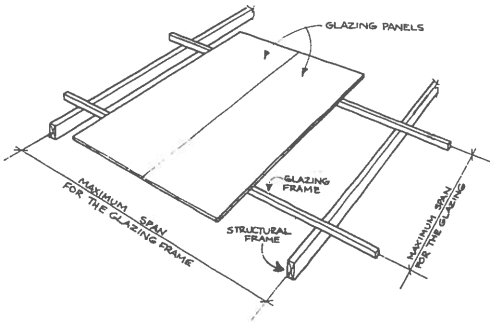
For characteristics which have not been quantified (e.g. probable life expectancy for many materials) the only reliable information is a manufacturer's guarantee, or a user's experience.

You should always check the information does in fact refer to the specific material under consideration.

Large samples of material should be examined closely before you select. It is also advisable that you visit existing solaria.

Note: Do not forget the choice of glazing must not be divorced from the choice of the glazing frame which will hold it in place and the structural frame that will support the whole solarium.





Criteria for Evaluating Glazing Systems

Transmittance of Solar Radiation

Product literature for materials used in greenhouse glazing often list light transmission only (e.g. the transmission of the visible portion of solar radiation.) **From an energy point of view, it is important to consider the transmission of the total solar radiation spectrum.**

A high transmittance of solar radiation is preferable. For a single sheet of glazing material transmittance of 0.75 could be considered adequate and a transmittance of 0.90 would be excellent.

Transmittance of Heat Radiation

This is the fraction of the total long wave radiation emitted from the solarium interior that will be re-radiated through the glazing to the exterior. Heat losses due to re-radiation were not included in the series of tables for Chapter 4 because they are small in relation to conduction losses. However, **a low transmittance of long wave radiation is preferable to a high one.** It is reasonable to demand a glazing material used for a solarium application have a long wave transmittance of less than 0.20. Glass is effectively opaque to long wave re-radiation.

Heat-Transfer Coefficient

This is a measure of the ease with which heat will be lost through the glazing assembly to the outside by conduction and convection. **A low heat-transfer coefficient is preferable to a high one.** The figures listed in A-1 may be used as a base for comparison with data found in product literature.

If the width of the glazing frame exposed to the outside is large in comparison to the total area of glazed surface, then conduction losses through the frame should be considered according to Tables A-2 to A-11. A low heat transfer coefficient is preferable for the frame material as well as for the glazing.

Air Infiltration

The overall assembly of glazing and glazing frame components should be examined for its ability to prevent the infiltration of cold air and the exfiltration of warm air. Assemblies which can successfully shed rain and snow may not necessarily be airtight. **The glazing assembly must provide an airtight enclosure.**

Glazing Factor

This is the fraction of the total area of glazed wall or roof which is actually glazing material. **A high glazing factor is preferable to a low one.**

Quality of Image or Diffusivity

Any material that allows light to pass through can be considered translucent. A translucent material that lets light through in such a manner that the image remains intact can be considered transparent.

In most solaria the users prefer at least part of the glazing be transparent to provide a view to the outside. Unfortunately, many high-transmittance glazing materials distort the view.

In solaria where the glazing is required to provide natural daylighting, a non-transparent glazing may be more appropriate because it will tend to diffuse the direct radiation, reducing glare and providing more balanced lighting.

Aesthetics

Some glazing materials are very flexible and unless they are restrained by the glazing frame, they can become irregular due to weathering. **It is suggested that you visit existing solaria before choosing any glazing material other than glass.** Some communities will not permit the glazing of any part of the parent building with thin plastic film. The framing materials should preferably be visually compatible with those of the parent building.

Durability

The life of the glazing system will be lengthened or shortened according to its ability to perform the following functions:

—Shed snow and rain from the outside face;
—Prevent the penetration of water and ice into joints of the outside face;
—Protect the main structural frame from exposure to temperature extremes or weather;
—Resist degradation by ultraviolet radiation;
—Resist degradation by alternating cycles of freeze and thaw;
—Resist the penetration of water into the glazing material itself if plants are grown in the solarium;
—Prevent the accumulation of condensation on cold points on the inside of the system;
—Shed any accumulation of condensation to troughs where it can be safely drained or evaporated away without causing damage;
—Withstand damage by small animals.

Cost

The cost of the glazing frame can be equal to, or even exceed, the cost of the glazing material itself. Both should be examined in relation to the durability factors mentioned above. The selection of glazing frame materials must be undertaken with a view to the maintenance that will be required.

Openings

It is necessary in most solaria to provide sections of the exterior wall or roof that can be opened to the outside. Often these openings must be placed in glazed sections and this will be more easily accomplished with some glazing systems than with others.

Support of Accessories

Most solaria will require a number of accessory items such as plant shelves, blinds, insulating curtains and lights. The possibility of integrating such accessories into the framing system will be important if there are insufficient areas of opaque wall or ceiling for this purpose.

Maintenance

Some glazing materials are very difficult to clean because they are too flexible, maintain a static charge which attracts dust, or are easily scratched. It must also be easy to remove and replace damaged glazing panes.

Guidelines for the Design of Glazing Systems

This section does not treat any glazing system in detail, but provides some basic design guidelines if you wish to construct your own framing system from basic materials.

You are encouraged to investigate new materials available on the market. For example, the plastics industry provides mouldings for curtain-wall systems which may be very appropriate as glazing frames, and offer better performance than wood when exposed to the elements.

Guide No. 1: Read the Manufacturer's Literature

It is absolutely necessary to acquire, read, and thoroughly understand the manufacturer's literature. It will seldom explain the limitations of a product, but will usually advertise the most suitable applications. It should also provide recommended procedures for installation and maintenance.

It is not always possible to follow these recommended procedures, but they must be understood in order to establish an adequate alternate solution. For example, the standard metal sections available with some glazing materials on skylights or curtain walls may be too expensive for the solarium application so a substitute system must be found.

The manufacturer's restrictions on maximum unsupported lengths, or areas must be respected.

Guide No. 2: Use Double Glazing

It is absolutely essential that double glazing be used in wintertime to avoid condensation of moisture on the inside face of the solarium glazing, as explained in the table below. Double glazing is composed of two layers of glazing material with an air space between. This insulating air space serves two functions:

—It reduces heat loss through the glazing by conduction.
—It ensures the temperature of the inside face of the inner layer of glazing is warmer than the temperature of the inside face of a single pane of glazing under the same conditions. Generally, this prevents condensation on the inside glazing surface.

Humidity and Condensation on Single and Double Glazing

Outdoor (°C)	Indoor (°C)	Relative humidity at which condensation may start to occur on single glazing*(%)	Relative humidity at which condensation may start to occur on double glazing*(%)
– 7	21	24	53
–17	21	12	41
–29	21	6	32
–40	21	2	23

**The relative humidity indicated in the table is the lowest relative humidity at which condensation may start to occur.*
Adapted from ***Walls, Windows and Roofs for the Canadian Climate****, National Research Council of Canada, Publication Number NRCC 13487.*

While these figures are approximate, they indicate that if the relative humidity in the solarium is maintained at a comfortable level, condensation will occur often on single glazing during winter. Because the bulk of air that passes through the solarium is actually air from the parent building, the use of double glazing will permit a more comfortable relative humidity in the parent building before condensation will occur on the solarium glazing.

A slight amount of window condensation or even frost is accepted in many homes on a few particularly cold days every winter. This effect should be controlled more carefully in a solarium for the following reasons:

—The large surface area of glazing will increase the total quantity of moisture produced. This moisture may damage the glazing frames and the finishes inside the solarium.

—The humid air from the parent building eventually passes by the glazing where the moisture will be lost from the air by condensation. This will dehumidify the air, cause discomfort to the occupants and increase the load on any humidifier operating in the parent building.

—Glazing condensation will reduce the transmissivity of the glazing and the effectiveness of the solarium as an energy provider.

Guide No. 3: Avoid Condensation Between the Two Sheets of Glazing

While double glazing is necessary, it creates the possible problem of condensation within the double glazing itself. This occurs because air's ability to retain moisture diminishes as its temperature drops. In cold weather, the temperature of the air in the space between the glazings will drop, and the moisture which can no longer be retained will condense.

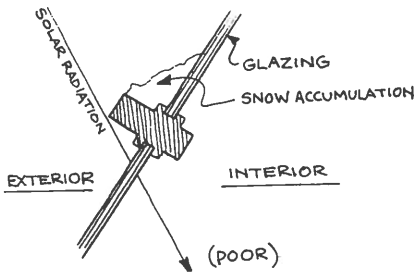
There are two principal methods for preventing condensation:

—Take measures to ensure the air between the two glazings is sufficiently dry — that is, the total quantity of moisture contained between the glazings is too small to cause condensation.

—Assemble the glazing so the outer layer is not perfectly airtight, but make the inner layer as airtight as possible. This will have the effect of slightly venting the insulating air space to the outside. While this venting will lower the effectiveness of the air space as an insulator, it will allow any condensation to escape.

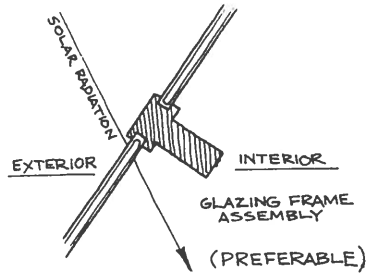
The first method is only possible with shop-assembled sealed glazing units. The seal around these units effectively prevents entry of any additional water vapour into the air space and a dessicant which is inserted into the air space during fabrication absorbs any moisture which is present.

Efforts to construct sealed double glazing on site from basic materials have not been successful because of humidity conditions on construction sites and poor tolerances possible using traditional materials and practice. Therefore, if the two layers of glazing are to be installed on the solarium independently one after the other, it is essential that great care be taken to make the inner layer as airtight as possible and the outer layer slightly vented.



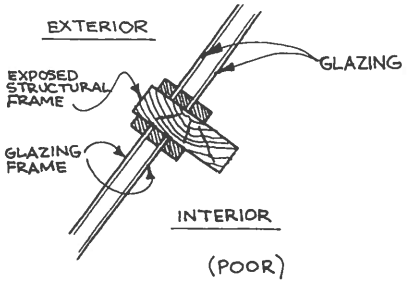
Guide No. 4: Provide Continuous Support Along the Edges of Every Panel of Glazing

Systems which join adjacent panels using intermittent fixations such as screws, or even using a glue or caulking material, with no continuous structural support along the joint, usually do not provide an adequate seal against air infiltration.



Guide No. 5: Install the Glazing Near the Exterior Face of the Glazing Frame

A glazing frame which protrudes beyond the face of the glazing on the outside will cause shading and snow accumulation.



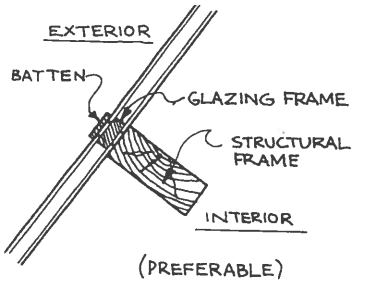
Guide No. 6: Protect the Structure from the Weather

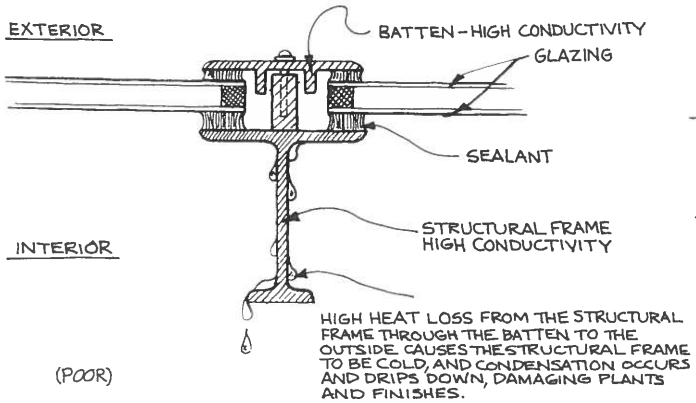
If the main structural elements are exposed to the weather, they will suffer the effects of temperature variations and moisture damage. Glazing frames or battens can be designed to protect the structure.

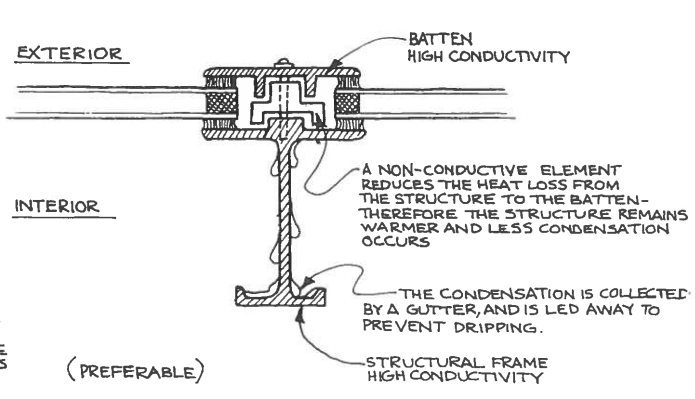
Guide No. 7: Avoid Thermal Bridges

Components made of materials which have a high conductivity (e.g. aluminum) should not be placed so that they are exposed to both the exterior and interior of the solarium. Less conductive materials, such as wood or plastic, can be used as a separation or replacement. This will prevent cold points where condensation will occur.

Because it is often difficult to eliminate these "thermal bridges" (i.e. points at which a highly conductive material passes completely through the building skin), it is wise to design the structure with small channels which will collect any condensate and lead it to where it can evaporate without staining or damaging the materials.




EXTERIOR
BATTEN - HIGH CONDUCTIVITY
GLAZING
SEALANT
STRUCTURAL FRAME HIGH CONDUCTIVITY
INTERIOR
HIGH HEAT LOSS FROM THE STRUCTURAL FRAME THROUGH THE BATTEN TO THE OUTSIDE CAUSES THE STRUCTURAL FRAME TO BE COLD, AND CONDENSATION OCCURS AND DRIPS DOWN, DAMAGING PLANTS AND FINISHES.
(POOR)


EXTERIOR
BATTEN HIGH CONDUCTIVITY
INTERIOR
A NON-CONDUCTIVE ELEMENT REDUCES THE HEAT LOSS FROM THE STRUCTURE TO THE BATTEN - THEREFORE THE STRUCTURE REMAINS WARMER AND LESS CONDENSATION OCCURS
THE CONDENSATION IS COLLECTED BY A GUTTER, AND IS LED AWAY TO PREVENT DRIPPING.
STRUCTURAL FRAME HIGH CONDUCTIVITY
(PREFERABLE)

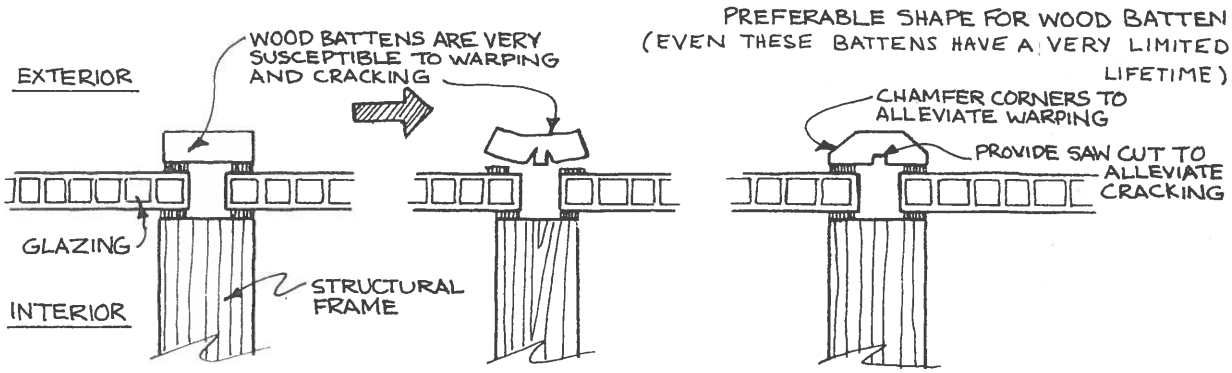
Guide No. 8: Shape Wood Members to Avoid Cracking and Warping

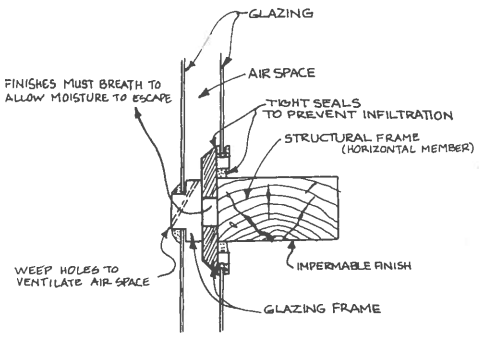
If glazing frames are to be made of wood, care must be taken (especially with battens) to avoid warping and splitting. The following procedures will not guarantee complete success because of the severity of this problem; however, they will reduce maintenance and repair problems:

—Use dry lumber that has been planed smooth to accept glazing and sealant materials easily.

—Treat the wood carefully against rot, carefully re-treating saw-cuts.

—Shape the components so they will be less likely to warp or split.


WOOD BATTENS ARE VERY SUSCEPTIBLE TO WARPING AND CRACKING
EXTERIOR
GLAZING
INTERIOR
STRUCTURAL FRAME
PREFERABLE SHAPE FOR WOOD BATTEN
(EVEN THESE BATTENS HAVE A VERY LIMITED LIFETIME)
CHAMFER CORNERS TO ALLEVIATE WARPING
PROVIDE SAW CUT TO ALLEVIATE CRACKING



Guide No. 9: Make Interior Face of the Glazing Assembly Air-and Water-Vapour Tight

To prevent the infiltration or exfiltration of air through the outside skin of the solarium and to prevent the penetration of water vapour from the inside into the joints of the assembly, use sealant materials and careful workmanship to ensure airtightness on the inside of the joints. Use impermeable finishes on the inside faces of the frames.

Guide No. 10: Construct the Outside Face of the Glazing Assembly to Shed the Weather and to Ventilate Moisture

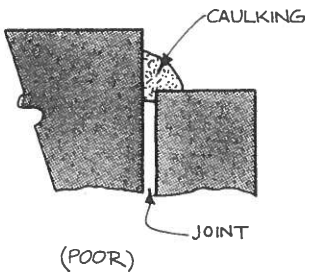
The inside of the joints should be perfectly sealed and the finish on the inside face of the members should provide a vapour barrier. However, the outside of the joints should not be sealed in such a manner that any moisture cannot later drain out. The outside face of the frame should be coated with a finish that will "breathe" to allow any moisture to evaporate to the exterior.

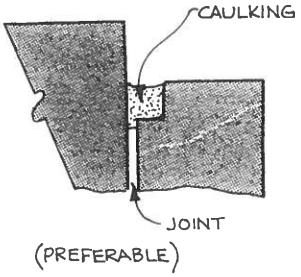
The configuration outside of the glazing assembly should allow moisture to drain off naturally. Provided the seal on the inside is good, there will be no pressure difference to force moisture into the assembly from the outside face.

Guide No. 11: Provide a "Seat" for Sealants

Caulking should be inserted into a slot rather than spread over a flat surface.

A sealant between two parallel-plane surfaces, with no "seat" formed by the configuration to contain it, must be of a type that will not simply spread out and leave unsealed areas along the joint.





General Note: This section contains some brief notes on a variety of subjects which are covered in far greater detail in the literature. If you are interested in pursuing these questions further, please refer to standard books on construction in the Canadian climate. The publications of the Division of Buildng Research, National Research Council of Canada are a good source.

Insulation

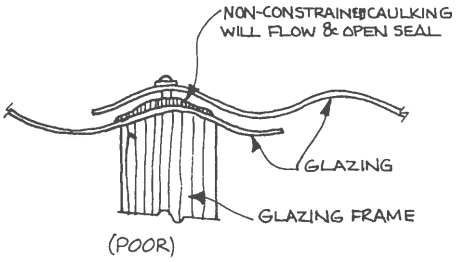
Fixed Insulation

The unglazed sections of the solarium envelope should be well insulated even if the solarium is to be allowed to cool at night. This insulation is required to reduce the heat losses that will occur while the sun is shining and the solarium is warm, yet the outside temperature is cold.

The optimum amount of insulation will usually be the same as that recommended for residential construction. Insulation standards are constantly changing to reflect the increasing cost of heating fuel. Refer to Canada Mortgage and Housing Corporation for these data.

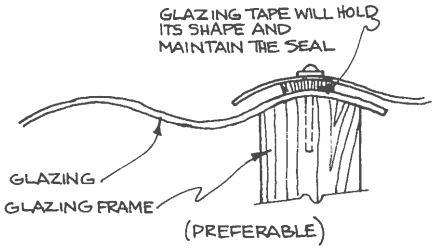
You may use the series of worksheets in Chapter 4 to predict the solarium's performance with an increase in the amount of insulation.

Insulation should be installed according to recommended construction practices, as described in *Keeping the Heat In,* and the manufacturer's instructions.



Insulating Curtains

Since energy can be lost from a solarium whenever the outside temperature is lower than the inside temperature insulating curtains can be used to reduce these losses. The curtains can either be flexible curtains or rigid panels, and they can be placed across either the inside face or the outside face of the glazing. They can be designed to reduce primarily radiation losses or both radiation and conduction losses. If the cost of making and installing them can be paid back by the value of the energy saved, they are considered cost-effective.



There are three major difficulties with insulating curtains:
(1) They can be expensive because of the technical problems involved.
(2) They are opaque, which means they are only useful when solar energy cannot be collected. (Some insulating devices are translucent or transparent, but these are considered as glazings.)
(3) Particular attention must be paid to ensure a good, airtight seal, so condensation does not cause problems.

Insulating curtains are not widely available commercially. A few manufacturers are starting to produce designs for individual windows, but most of these do not suit solaria. For the forseeable future, most solarium owners will have to design and fabricate insulating curtains themselves.

Because of the design difficulties, a popular solution to the problem of heat loss is currently to forego insulating curtains completely and to allow the solarium to cool off at night. It has proven much simpler to install insulating dampers or louvres on openings between the parent building and the solarium to prevent heat loss to the solarium in the first place. However, if you wish to use the solarium at

any time of day, insulating curtains are essential and the following design criteria may be useful:

Insulation Value

The terminology used to describe the effectiveness of ordinary insulation—thermal resistance, *R*, and heat transfer coefficient, *U*—may also be used for insulating curtains. These values describe the ability of the curtain to reduce heat loss by conduction. The optimum amount of insulation for the curtains must be chosen considering:

—The cost of the insulation.
—The gain in solarium performance predicted by the calculations in Chapter 4.
—The technical ease of incorporating that amount of insulation in a curtain or panel that is easy to operate.

In some greenhouse operations, inexpensive insulating curtains which are simple reflecting sheets have proven effective despite very small *U* values. The reflecting curtain reflects the heat radiated from the ground (thermal mass) back into the greenhouse space, and this is sufficient to keep the growing space warm despite the losses due to conduction.

A solarium may be designed to operate in a similar way, with a large thermal mass built into the solarium space as explained later in this chapter. You must remember such a solarium may be kept warm at night with insulating curtains, but it will provide much less energy to the parent building during the day.

Airtightness

Insulating panels or curtains must be designed so there are no cracks or holes through which warm air from the solarium space may leak to the glazing or other cold surfaces. This means that all the edges of the individual curtains or panels must be made to fit tightly against one another or against an element of the frame.

Reflectivity

The inside-facing finish of the insulating curtain must be able to reflect heat radiated from the inside of the solarium back into the solarium space. The outside-facing finish should also be reflective (if possible) and have a low emissivity to prevent high losses by radiation.

Ease of Operation

It is obviously extremely important that insulating curtains be designed to operate very easily so they will be used. You should give special attention to the choice of hardware, since a system with average insulation value, that operates easily, will probably provide greater heat savings than a system that has high insulation value but is an annoyance to operate.

While this appears a formidable problem, there are studies underway to develop night curtains for solaria, greenhouses and large windows. It would, therefore, be wise to keep abreast of these developments. In the interim, well fitted, heavy drapes or curtains, in combination with venetian blinds and shades, can reduce heat losses.

Storage

The insulating curtains must either fold or roll away into a convenient storage space. Provision for this space must be made early in the design stage, preferably in the preliminary design, to ensure the storage does not obstruct the glazing. This will usually be easier with flexible curtains than with rigid panels.

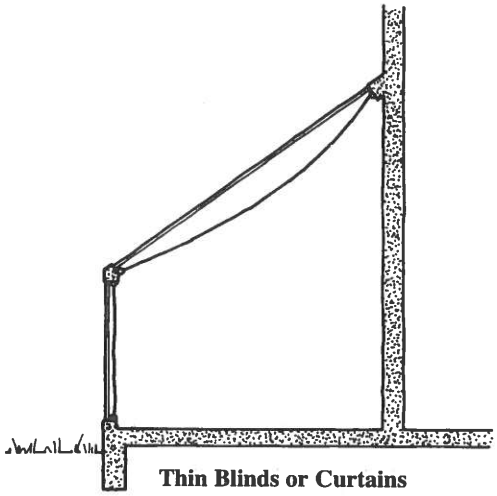
Durability

The whole system must be resistant against puncture, abrasion and tearing. If the solarium is a greenhouse, it must also withstand high humidity.

Insulating Blinds, Curtains & Panels

Thin Blinds or Curtains

A simple curtain or blind will reduce radiation losses, but will have little effect on conduction losses unless it is well sealed around all edges to provide an extra insulating air space between the blind and the glazing.



Thin Blinds or Curtains

Insulated Blinds

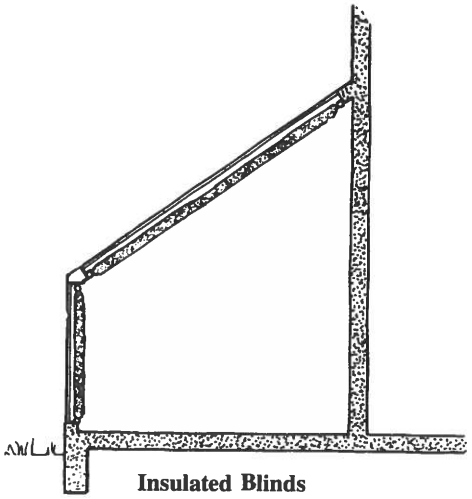
Insulation material, such as that used in sleeping bags, can be sewn into a curtain or blind to provide extra *R* value. It is still very important to seal around the edges of the air space that is formed between the glazing and the quilt.

Expanding Blind

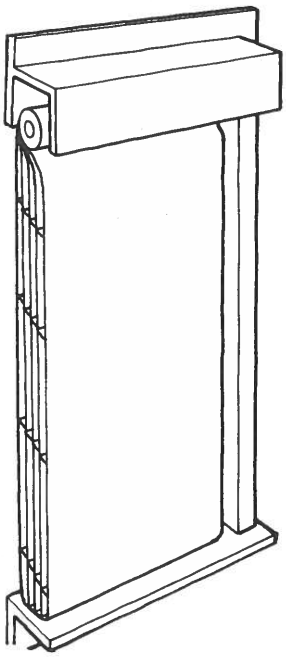
These are manufactured in the United States for window installations. A roll-down blind is made of several layers of reflective film which separates when the blind is pulled down. This forms several air spaces which serve as insulation.

Insulated Roll-Up Blind

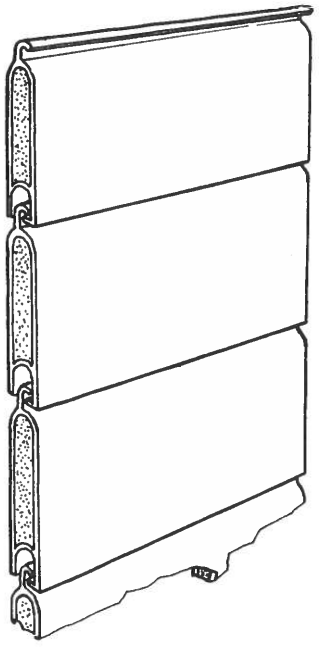
These curtains are presently available commercially in Canada for installation on standard windows. Rigid insulation is sandwiched inside each slat. The slats are held together by a tongue-and-groove arrangement which allows enough flexibility for the slats to roll up into a storage unit.



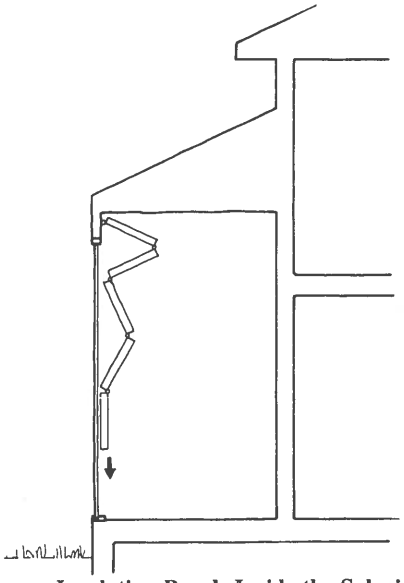
Insulated Blinds



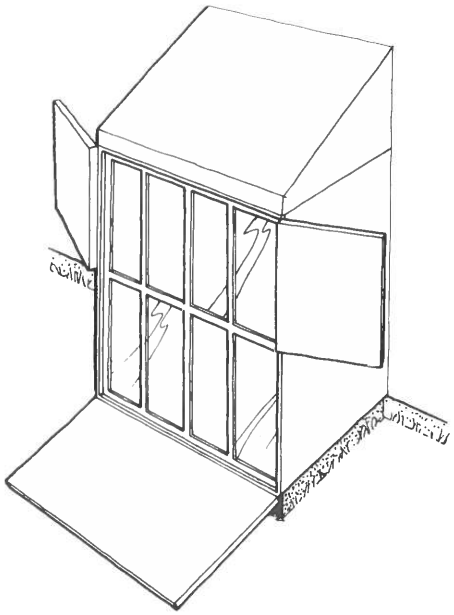
Expanding Blind



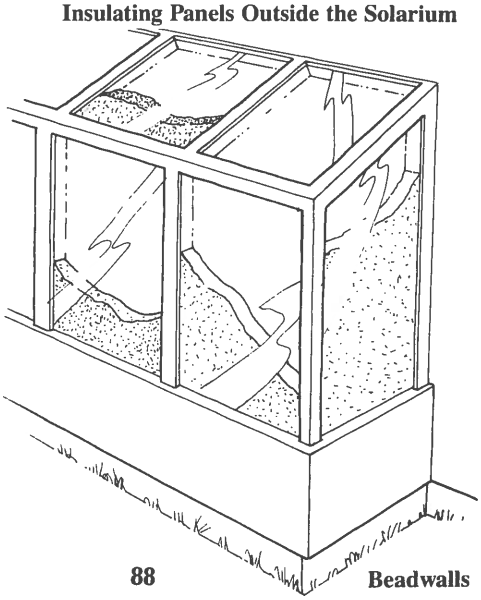
Insulated Roll-Up Blind



Insulating Panels Inside the Solarium



Insulating Panels Outside the Solarium



Beadwalls

Insulating Panels Inside the Solarium

Though a high *R* value is possible with these panels, there are some considerations that must be kept in mind:
— it is difficult to prevent heat loss through the joints between the panels.
— they can be heavy.
— a space must be allocated for panel storage.
— panel operation can interfere with objects, e.g., plant supports, inside the solarium.

Insulating Panels Outside the Solarium

These panels can offer a high thermal resistance (*R* value) and avoid the difficult storage problem inside the solarium. They are, however, exposed to damage by the elements. Opening and closing of the panels will probably be difficult in inclement weather. The panels may act as reflectors while they are open to increase the radiation intensity on the solarium.

Beadwalls

They are presently available for residential applications in the United States and are being developed in Canada for commercial greenhouse applications. The space between the double layers of glazing is filled at night with beads of rigid insulation material, and the beads are withdrawn the following morning. The beads are carried to and from the airspace by a flow of air. Air spaces as large as four inches have been used with bead walls. Storage containers and ductwork for the beads must be carefully integrated into the design of the solarium.

Sun-Control Devices

While the sun is shining on the solarium, it may become uncomfortably hot inside. It is therefore a good idea to provide devices that can protect the solarium from direct sunshine when heat is not required by the parent building. The solarium space can then be kept comfortable and useful.

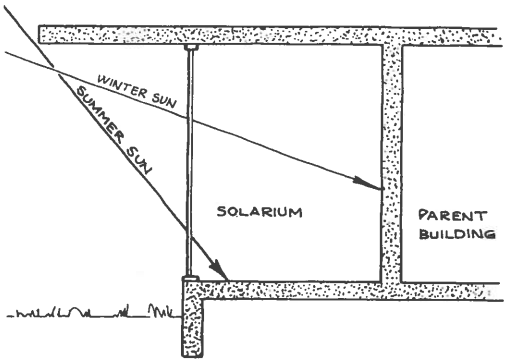
Available alternatives include:
— roll-up, roll-down shades of redwood slats, usually applied to the exterior of the structure;
— internal shades of virtually any type for vertical surfaces only;
— internal roll-up, roll-down fabric shades supported by wires or some alternative, suitable for both vertical and horizontal surfaces;
— plastic film;
— liquid shading applied either externally or internally. This is a temporary measure and can be easily removed;
— roof overhangs and awnings;
— climbing plants;

Note: Internal shades should be light-coloured and the surfaces as reflective as possible to reduce the heat collected.

Unlike insulating curtains, sun shades do not have to be perfectly air-tight, sealed around the edges, or have an insulating value. They are, therefore, much easier to design, fabricate and install, and they are consequently much less expensive.

Roof Overhangs and Awnings

Roof overhangs and awnings can be designed to protect the solarium glazing from the high summer sun while leaving it exposed to the lower winter sun.



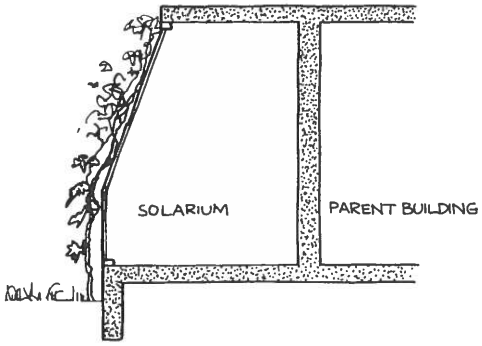
Climbing Plants

If allowed to grow up against the solarium glazing in the summer, plants will protect it from excess sun. They can be cut back in the autumn to expose the glazing to the winter sun.

Deciduous trees, if positioned appropriately will perform the same function.

Sun Shades

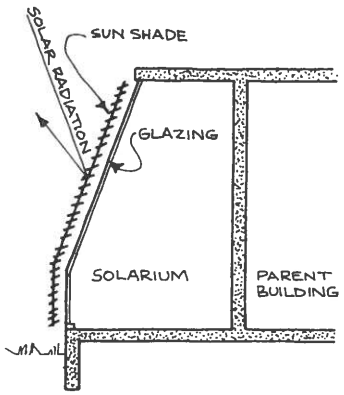
While the operation of sun shade devices may be more convenient if they are placed inside the solarium, they will usually be more effective if placed outside the glazing because heat will not build up between the glazing and the shade.



Interior Finishes

"Interior finishes" refers to the materials which can be seen from the inside, on the ceiling, floor and walls, after construction has been completed. The basic criteria for the choice of any finishing material are:

- aesthetics;
- durability;
- ease of maintenance;
- cost.



It is important that the materials be able to withstand such conditions as a high degree of radiation, which tends to fade bright colours; high humidity; and heavy traffic. It is important to establish your durability and maintenance requirements so that inappropriate materials can be eliminated right from the start. Some finishes also adapt more naturally to certain types of construction. With these considerations in mind, if there are some materials which you prefer, they should be identified at the design stage and integrated with other materials.

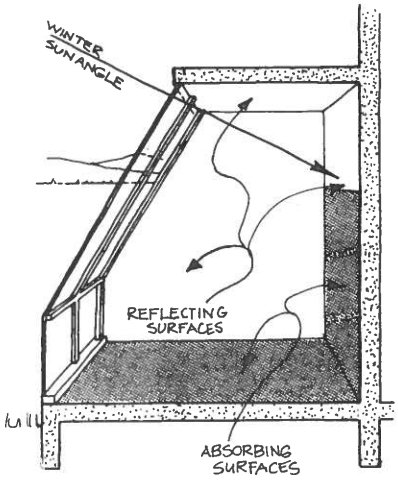
The role of the solarium as an energy provider will require some special consideration as to the selection of finishes. preferably, the solarium will be bright with light-coloured finishes which will reflect visible radiation and allow for maximum daylighting. However, if all the finishes were to be very reflective, this radiation would simply be reflected from one surface to another and eventually refelcted out again. **It is, therefore, imperative that some surfaces be finished with a material which has a high absorptivity to radiation.**

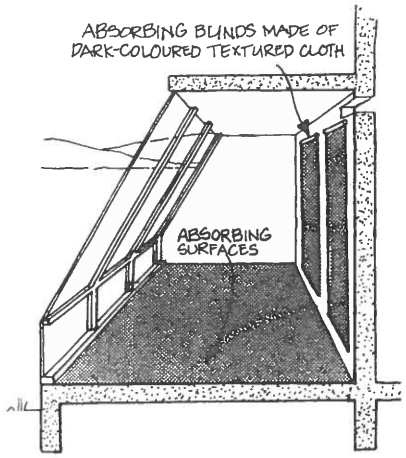
The first task in choosing interior finishes is to decide which surfaces will be absorbing.

To provide an optimum balance of natural daylight and solar energy collection, the following guidelines can be used:

- Design the floor to be an absorbing surface.
- Design shaded areas such as ceilings and upper portions of the walls which never receive direct radiation to be reflecting surfaces.
- Design end walls (i.e., east and west walls) to be reflecting surfaces.
- Design those portions of the rear (north) wall which receive direct radiation to be absorbing surfaces.

If it is not important to provide natural lighting in the solarium, all the surfaces may be absorbing. If daylight is a priority, however, more surfaces should be reflective; but absorbing blinds should be provided so the energy performance of the solarium is increased when daylighting is not required.





Absorbing blinds or curtains will permit all the interior finishes to be reflective. The blinds should be placed in the path of direct solar radiation, but as far inside the solarium, away from the glazing, as is convenient. This is to reduce the heat given off from the blinds being lost through the glazing. The one exception to this rule is placing the blinds on the end walls to prevent the solar radiation from passing directly through the solarium.

Reflecting surfaces should ideally be reflective to all wavelengths in the spectrum of solar radiation. Practical finishes are gypsum board or exterior wood siding installed on wood-frame construction and painted white.

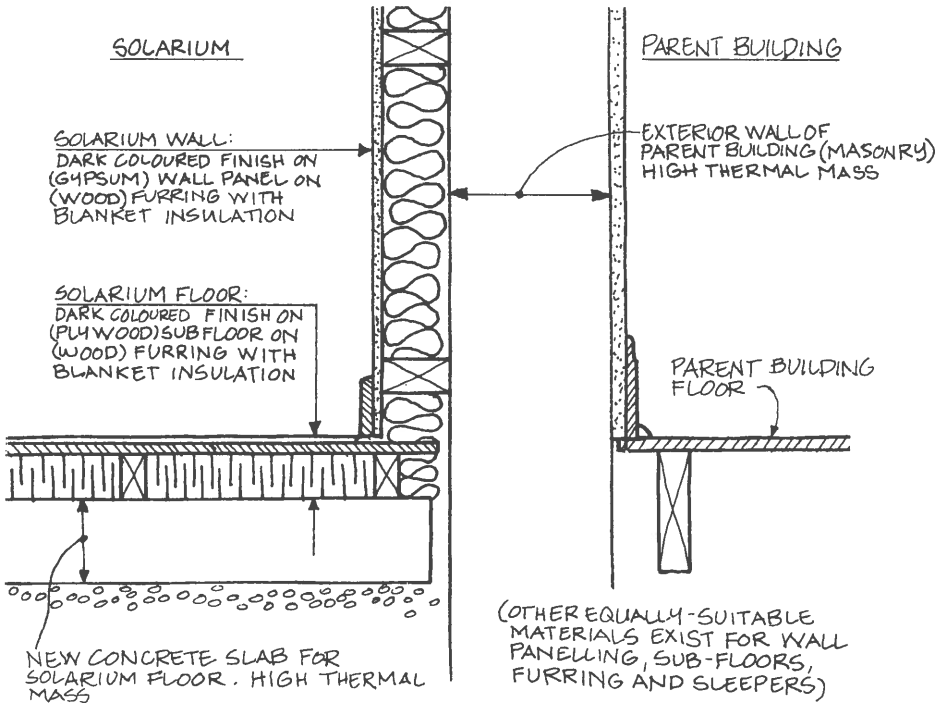
Absorbing surfaces should ideally be absorptive to all wavelengths in the spectrum of solar radiation. Experience has shown that dark finishes will be most effective. The texture must be a matte finish to avoid reflection.

There are some special absorbing finishes, called selective surfaces, which absorb solar radiation but emit very little heat radiation. However, they are quite inappropriate for a solarium because they are usually very expensive and easily damaged.

Type 1 Solarium: Supplier of Heat

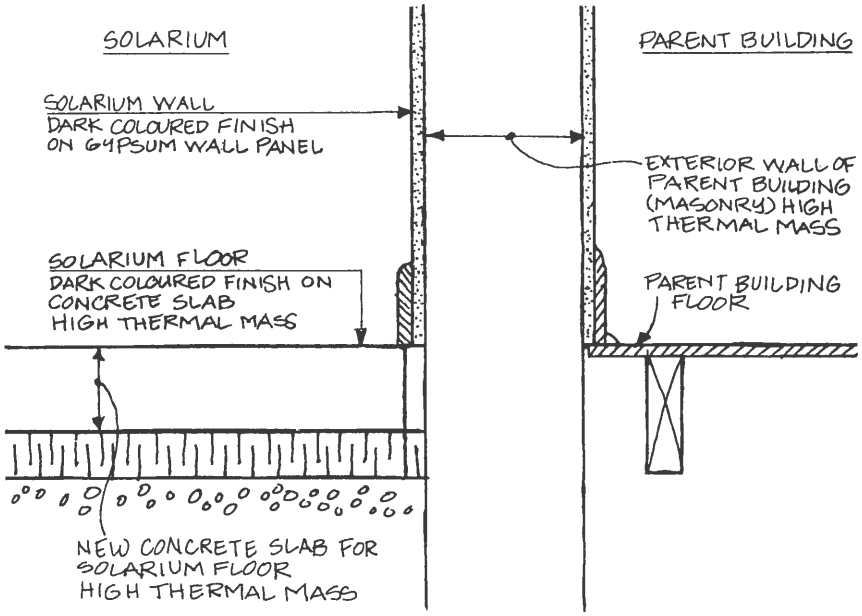
If the solarium is principally a supplier of heat, its absorbing surfaces should have a low thermal mass. Then, as solar energy is absorbed by the finish, it will not be retained within the absorbing surface, but will be transferred to the solarium air by conduction. In this manner, the solarium air will be heated and can be drawn away to heat the parent building. Dark-coloured matte paint, on gypsum board or wood panelling, is a suggested finish. If the walls are masonry (and therefore have a considerable thermal mass), dark paint can be applied to a new surface of gypsum board attached to the masonry to lessen heat transfer.

Absorbing floors can be finished with any dark-coloured vinyl-asbestos tile, baked earth tile or carpet. However, if the sub-floor is a concrete slab, you should first build a plywood sub-floor on wood-frame sleepers over the slab. The space between the slab and the plywood sub-floor should be insulated to lessen heat transfer to the slab.


SOLARIUM
PARENT BUILDING
SOLARIUM WALL: DARK COLOURED FINISH ON (GYPSUM) WALL PANEL ON (WOOD) FURRING WITH BLANKET INSULATION
EXTERIOR WALL OF PARENT BUILDING (MASONRY) HIGH THERMAL MASS
SOLARIUM FLOOR: DARK COLOURED FINISH ON (PLYWOOD) SUBFLOOR ON (WOOD) FURRING WITH BLANKET INSULATION
PARENT BUILDING FLOOR
NEW CONCRETE SLAB FOR SOLARIUM FLOOR. HIGH THERMAL MASS
(OTHER EQUALLY-SUITABLE MATERIALS EXIST FOR WALL PANELLING, SUB-FLOORS, FURRING AND SLEEPERS)

Type 2 Solarium: Heated Space

If the solarium is principally a heated space, the interior surfaces should have high absorptivity, high conductivity, and a large thermal mass. The finish should not be insulated from the thermal mass, so absorbed solar energy may be easily conducted into it. Later, as the solarium starts to cool off, this energy will be conducted back into the solarium and will help lessen the heat load on the auxiliary heating system. An appropriate finish for such absorbing surfaces is dark-coloured paint applied directly to a masonary wall or a concrete floor. If the masonary is a dark colour, no finish is required. Carpets are inappropriate for this type of solarium because they will lessen heat transfer into the concrete slab.



Heat Storage

There are basically two distinct approaches to the solar heating of buildings: active and passive.

Active systems use hardware and mechanical equipment to collect and transport heat. Collectors are usually mounted on the roof of the building and there is often a separate heat-storage unit—a rock bin or water tank. Water or air pumped through the collector absorbs heat and transports it to the storage unit. This heat is then supplied, when needed, by a distribution system.

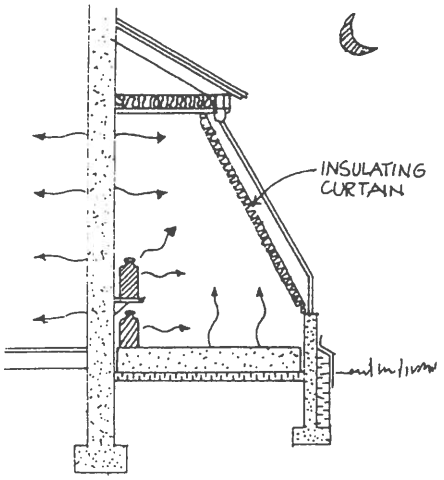
Passive systems collect and transport heat by non-mechanical means. Thermal energy flows by natural means, such as radiation, conduction, and natural convection. In essence, the building structure *is* the system. There are no separate collectors, storage units or mechanical elements. The most striking difference between the systems is that the passive system operates on the energy available in its immediate environment, whereas the active system imports energy, such as electricity, to power the fans and pumps which make the system work.

Active Heat Storage

A solarium is in fact a large solar collector. It is possible to duct some of the air heated in the solarium into a heat store, just as warm air is ducted from solar collector panels to a heat store in typical active solar systems.

However there is one important difference between a solarium and an air collector system: the former operates at much lower temperatures than the latter (approximately 25°C as opposed to 60°C). The energy collected by a solarium and a comparably sized collector array will be similar but the low-grade heat from the solarium will need a much larger volume of rock-bed storage. This storage unit may seem simple to build, but it does need a good support structure and some careful attention to design. (The Solar Energy Project of NRCC does have some contractor reports available on this subject.) Without going into any more detail, it can be stated that in most cases the active rock-bed storage used in conjunction with a solarium would be difficult to justify economically.

Development is continuing of phase-change storage materials which can work effectively with low-grade heat. One such material, Glauber's salt ($Na_2SO_4 \cdot 10H_20$), changes from a solid to a liquid at 32°C. The heat of fusion for this phase change is substantial so that even for modest differences of temperature about this melting point considerable energy can be stored. Recent work appears to have solved problems encountered with the disassociation of the salt (it would only go through a very limited number of cycles of liquification and solidification). Also it has been shown that the temperature of fusion can be easily reduced to lower values appropriate for solaria by the addition of common salt. Nevertheless this material, which should permit more compact storage units, will have to be very modestly priced to warrant its use.



Thermal Mass

As discussed in the introduction the desirability of using thermal mass within the solarium depends very much on its type. If you do intend it to be a greenhouse or to accentuate its use as a living space then thermal mass should be incorporated into the solarium. Its principal function will be to moderate the large swings in temperature through the day/night cycle.

Useful materials for thermal storage should have a high volumetric heat capacity and good conductivity. Some construction materials' heat capacities are listed below.

Construction Material	Volumetric Heat Capacity ($kJ/m^3 \cdot °C$)
Water	4 186
Steel	3 600
Limestone rock	2 300
Concrete	2 000
Brick	1 600
Soil (highly dependent on moisture content)	1 200 to 3 700
Wood (dependent on moisture content and type)	700 to 1 400
Gypsum board	900

For the thermal mass to be most effective, it should be distributed throughout the solarium and directly exposed to the solar radiation. Slabs of material should be no thicker than is necessary to absorb the heat during the day. For concrete slabs 10 to 20 cm. is ideal; for wood with a lower conductivity little effective mass is gained beyond 5 cm.

To avoid excessive heat loss at night the thermal mass should not be in the immediate proximity of the glazing.

A simple calculation can be performed to evaluate the order of magnitude of the thermal mass you need. It is necessary to specify an allowable temperature, perhaps determined by the tolerance of your plants, and the net energy gain per day during the coldest month, when this energy is most useful. Then the volume of storage needed of any material is:

$$V = \frac{\textit{net heat gain per day}}{\textit{heat capacity} \times \textit{temperature rise}}$$

This method is only very approximate, especially for a greenhouse, since much of the solar energy will go into evaporation of water from plants and soil.

In the example of Chapter 4, the net heat gain per day in January was 13 kWh. If one intends to use concrete slabs for the thermal mass with a 16°C tolerance in temperature fluctuation then the volume, V, needed to store this energy is:

$$V = \frac{13 \text{ kWh}}{(2\,000 \text{ kJ/(m}^3 \cdot \text{°C)}) \cdot 16\text{°C}}$$

$$1 \text{ kWh} = 1\text{kJ/s} \cdot 3\,600 \text{ s/h} = 3\,600 \text{ kJ}$$

$$V = \frac{13 \cdot 3\,600}{2\,000 \cdot 16} \cdot \text{m}^3 = 1.5 \text{ m}^3$$

A wall with a thickness of 10 cm would need to have an area of

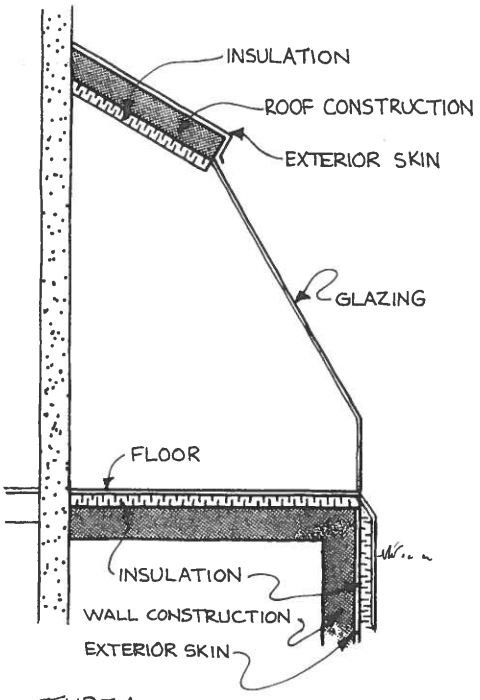
$$A = \frac{V}{t} = \frac{1.5 \text{ m}^3}{0.1 \text{ m}} = 15\text{m}^2$$

In our example this would just about be the entire back surface of the solarium, which was 2.56 cm by 6 m. Of course, one should also account for some of the other thermal mass within the solarium.

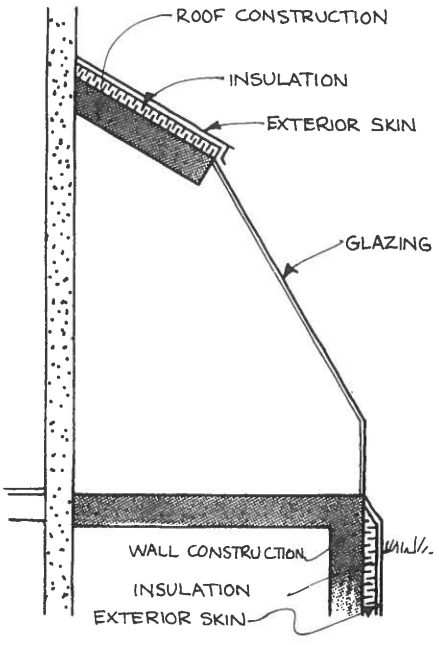
The thermal-mass-needs vary with the type of solarium being constructed.

If the solarium is to be used solely as a solar collector (Type 1 solarium), the insulation in the floor, walls, and roof should be placed on the inside of the solarium to exclude the thermal mass of the construction materials. This will maximize the heat gain by the solarium air and hence the heat transfer to the parent building.

If the solarium is to be a heated space (Type 2 solarium), the insulation should be placed on the outside of the floor, walls and roof structures to include their thermal mass inside the solarium. Keep in mind that the location of thermal mass is important. You should try to spread it around as much as possible to have the maximum surface area exposed to direct solar radiation. It is also preferable to keep the thickness of the heat storage material to a minimum, since it takes time for conductive heat transfer to carry the heat from the surface to the core of the material.



TYPE 1



TYPE 2

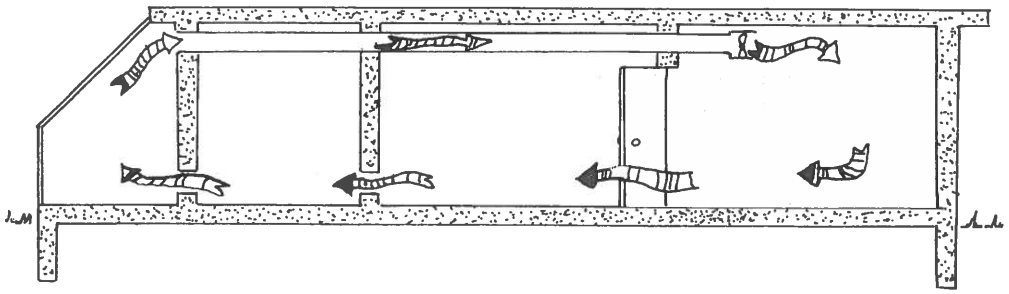
NOTE care must be taken in the design of construction details to avoid conductive heat losses through thermal bridges. The insulation should ideally form a continuous layer all around the heated spaces.

Distribution of Air Through the Parent Building

You must choose a destination for the warm air coming from the solarium. If the solarium is a small glazed balcony and if there is an appropriate destination space adjacent to it, heat can be transferred most easily by opening the window and/or the door leading to the balcony. The movement of air may be assisted by a

portable fan or by mounting a window-type fan at the top of the window. A larger solarium heating an adjacent space will require exhaust and return ports in the common wall. Both parts will need dampers, and the exhaust port will need a fan.

If the destination for the warm air is not adjacent to the solarium, a duct system will be required. The force of thermosyphon will usually be insufficient to carry air through a duct, so a fan will be required at either end of the duct.

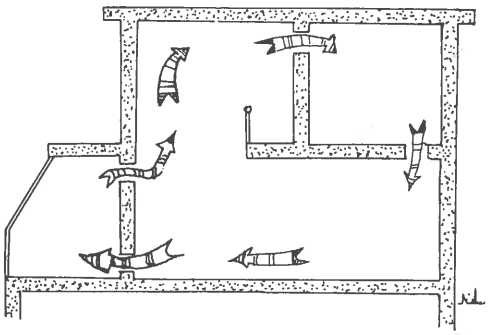


It is preferable to install the fan in the exhaust port, drawing warm air out of the solarium. This puts the solarium under a small negative pressure which in turn forces leakage of cold air from the outside into the solarium. If the solarium was under positive pressure, there would be leakage of warm air to the outside, which is a net loss of efficiency. A return duct may then not be necessary to carry air back to the solarium; the negative pressure in the solarium will pull the air back through open doorways.

The destination space must be suitable for the amount of warm air that the solarium can supply. If the destination space is small, and there are times when the hot air overheats the space, some of the warm air should be directed elsewhere. If the space is large and the warm solarium air is inadequate at times to maintain a comfortable temperature, a supplementary heat source may be required. This is usually done by adjusting the existing heating system of the parent building. In addition, large thermal mass is ideal in the room receiving heated solarium air. The incoming heat will be sorted by the mass and released when it is needed at night.

A basement can be an ideal destination space for the solarium air, provided it is:
- dry throughout the year (no seepage or flooding);
- well insulated on the outside;
- free of objectionable odours;
- clean.

The thermal mass of the basement will easily absorb the heat from the solarium air. The stairwell from the basement to the ground floor must be left open to allow the heat to rise naturally.



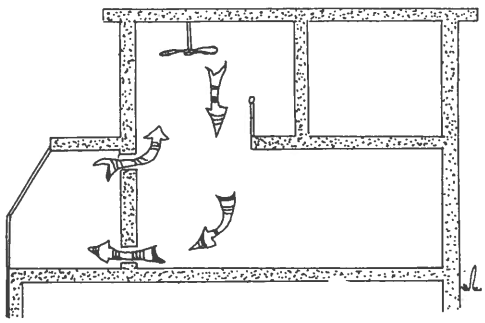
Openings may be pierced in the walls and floors to permit circulation of air through the parent building. Warm air can then escape from spaces in which it might otherwise be trapped.

Care must be taken to ensure an effective circulation of air throughout the entire system. The warm air from the solarium moves by convection and/or mechanical means to the destination where it displaces cooler, denser air. As the air cools, it falls and attempts to return to the solarium, which is a low-pressure zone when its air is being heated and exhausted back to the parent building. It is very important the heat from the solarium be delivered to where it can be gainfully used, and the return-air path is kept as free as possible of obstructions. This movement must therefore be coordinated with the existing air movement in the parent building.

The distribution of air throughout the parent building may require mechanical assistance. Warm air that rises and is trapped at the peak of high spaces should be

driven downwards by a ceiling fan. Small, unused rooms at the top of the building should also be closed. Extra openings may be provided in walls and floors to provide better circulation. Cold air, on the other hand, will fall and seek the lowest available point in the building. Whenever possible, this natural tendency should be used to achieve the desired distribution of hot air from the solarium. However, when the desired movement is not in accord with the natural movement, mechanical means must be used.

Currents of hot or cold air, occurring particularly at duct openings, are uncomfortable to occupants and must be avoided. In addition, the short-circuiting of air from the solarium exhaust back to the return without ever reaching its destination must be prevented.



Warm air drawn from the solarium may rise as it enters the parent building and become trapped at the top of a high space.

A ceiling fan may be used to force this trapped air back down nearer the floor.

Remember both sound and odour can follow any path open to air movement. Sound may create a more difficult problem than odour because it can travel both ways along a duct.

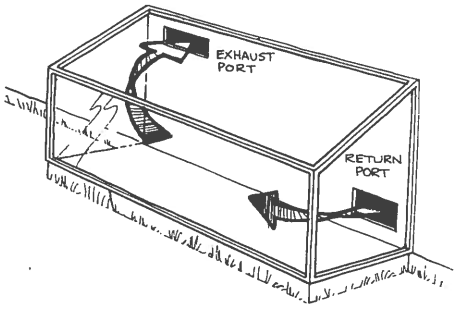
It is recommended that you consult an engineer before integrating the flow of air from a solarium into the forced-air heating system of a parent building. The openings for the solarium air must be carefully placed so the two systems operate simultaneously, but independently.

Several factors should be considered when deciding the location of the exhaust and return ports in the solarium:

—Warm air should be drawn out at the top of the solarium, and cooler air returned at the bottom.

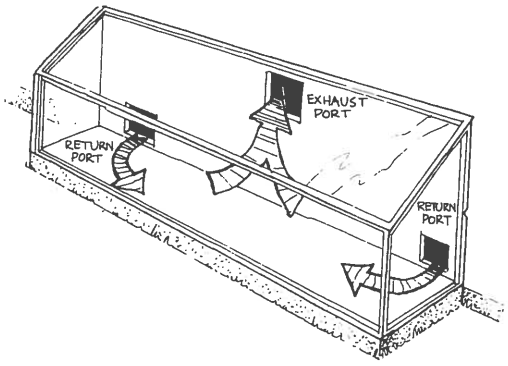
—Ports should be placed far from each other to encourage a flow of air through the solarium.

—More than one exhaust or return port may be used, to suit the size of the solarium and the pattern of air distribution to the parent building.



Passive Air Distribution

Warm air from the solarium may be moved to an adjacent part of the building using the natural flow of air by thermosyphon. Provided the exhaust and return ports are large enough and properly placed, no fan will be necessary. As a general rule, the total wall area left open by the ports should be at least one-sixth of the solarium floor area if no fan is to be used. The total area of the exhaust ports should be one-third larger than that of the return ports.



Active Air Distribution

The advantages of forced air movement are as follows:

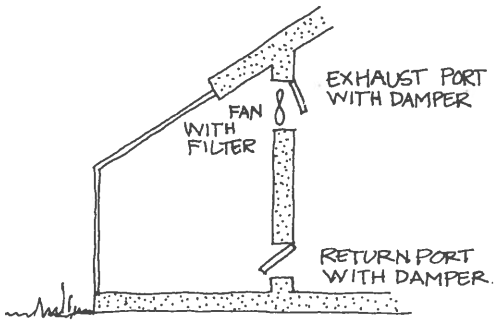
- A fan is easily controlled automatically.
- A fan can move air to a space remote from the solarium, through a duct.
- A fan can move air more quickly than a thermosyphon and so smaller ports are required.
- A fan can be combined with a filter to reduce the amount of dust in the air.

The disadvantages are:

- A fan requires electricity.
- Some fans are noisy and must be located where they will not be a nuisance.
- Fans require maintenance and filters frequently need cleaning.

Equipment

The following is a list of equipment normally needed for an active air-circulation system:



- an exhaust port with a damper
- a return port with a damper
- a fan with a filter
- controls
- ducting, in some cases.

Fan Selection

Many types of fans are available and prices vary greatly. Before purchasing, a fan should be examined according to the following criteria:

- The fan's capacity and head (pressure) should be examined.

- The fan should be tested to determine the noise level of its motor. Because a noisy fan must be installed where it will not create a disturbance, it may be preferable to spend more for a quieter one which can be installed where it is most functional.

- The rotation of the fan blades should be smooth. If the mechanism vibrates, it will wear out quickly and create noise.

- The fan may come with filters and louvres as accessory items. If not, the compatibility of the fan with the filters and louvres to be used must be verified.

- The fan must also be compatible with the overall system and be powerful enough to move air through the full length of the ductwork.

- Since all moving equipment requires maintenance, you should check that maintenance instructions are furnished with the fan.

- The guarantees offered by manufacturers may give a comparative indication of fans' life expectancies.

- If the unit is installed in a visible location it should be compatible with the decor.

- The fan's power requirements obviously must be compatible with the service in the house or building.

Ductwork

To reduce resistance to the air flow, ducts should be smooth, have a minimum number of bends and angles, and be of a minimum length.

Ducting should be made of galvanized steel, aluminum, or some other suitable fire-rated material. Where ducts pierce a fire wall or a fire separation, they must be equipped with approved fire dampers.

A duct which carries warm air through an unheated space should be insulated around its perimeter. However, the temperature of the air being exhausted from a solarium is insufficient to warrant insulation around a duct which passes through a heated space.

ICFM = **.0283m³/min**
1 inch of water = **249 Pa**

Fan Capacity and Size of Duct

If for the same solarium described in Chapter 4 it is decided to provide two fans, each with a capacity of* 10 m³/min, *each fan should lead to a duct that has a cross-sectional area of at least* 550 cm² *(rounded value). This could be a rectangular duct* 250 mm × 225 mm, *or a round duct* 300 mm *in diameter.

The capacity of a fan is described by:

- The quantity of air which it can move within a certain time, usually expressed in cubic metres per minute (m³/min) (or cubic feet per minute-CFM).

- The pressure at which it can transfer this quantity of air, usually expressed in pascals (Pa) or inches of water.

The quantity of air required (m³/min or CFM) will be determined by the number of air changes required to maintain the desired temperature in the solarium. This value may be obtained by dividing the volume of the solarium by the time interval between changes. As a general rule, it should be possible to completely change the air in a solarium (such as the example discussed in Chapter 4) within two to

four minutes.

The pressure required for the fan will depend upon the amount of force required to move the air through openings, along ducts and around elbows and other obstructions. This will depend upon:

— the cross-sectional area and shape of the duct.
— the length of the duct
— the number of bends in the duct.

The cross-sectional area of the duct required to convey the air should be selected so the velocity of the air in the duct does not exceed 180 m/min (600 ft/min). The cross-sectional area is obtained by dividing the capacity of the fan leading to the duct by the maximum air velocity of 180 m/min.

The pressure required for the fan can be established from the following guidelines. (Note that for each bend in the duct an equivalent extra length of duct is added, to account for the extra pressure required.)

Size of Duct (mm)	Equivalent length to be Added for Each Bend (m)	Pressure Required per Metre of Duct Length at 180 m/s (Pa)
100 dia	2	1.65
150 dia	4	1.00
200 dia	5	0.65
250 dia.	6	0.50
100 × 100	2	1.65
100 × 200	4	1.00
125 × 150	5	0.65
150 × 225	5	0.65
175 × 200	5	0.65
225 × 250	6	0.50
250 × 250	6	0.50

At each end of the duct, one must assume an additional pressure requirement of 7.5 Pa as an entrance or an exit loss.

If a fan leads directly from the exhaust port to the destination space, the pressure requirement is 30 Pa. This value exceeds the sum of an entrance loss plus an exit loss because the air flow cannot stabilize between entrance and exit as is the case in ducted flow.

Fitting this duct to the exhaust port in our example, the fan capacity will then be 10 m^3/min at a pressure of 24 Pa.

In summary, the precedure for establishing the size of fan required is as follows:

– Calculate the volume of the solarium.
– Calculate the air flow rate required by the fan to exhaust this volume of air within 2 to 4 min.
– Calculate the cross-sectional area of duct required (if a duct is needed) to move this volume at a velocity of less than 180 m/min.
– Establish the path this duct will take, to determine the length and the number of bends.
– Calculate the pressure required by the fan to overcome the resistance of this path.

Fan Power

The procedure presented above is adequate for fan selection. You may, however, want to calculate the required fan-motor power corresponding to your design in order to calculate the operating cost of your air-distribution system.

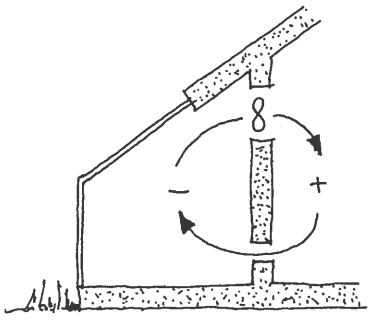
The fan power is given by:

$$\textit{Fan Power (W)} = \frac{\textit{Flow Rate} \times \textit{Pressure}}{60 \times \textit{Fan Efficiency}}$$

This particular solarium has a volume of* 40 m^3 *so it requires a fan (or fans) with a total capacity between* 10 *and* 20 m^3/min *(*350 *to* 700 *CFM).

For example, if one of the* 250 mm × 225 mm *ducts mentioned above is* 6 m *long and has two bends, it will require from its fan a pressure of:

6 × 0.50	= 3 *Pa due to length*
2 × 6 × 0.50	= 6 *Pa due to bends*
2 × 7.5	= 15 *Pa due to the exit and entrance losses*
	24 *Pa*



In our example, the power requirement of the fan selection given in the previous section is:

$$\textit{Fan Power} = \frac{10 m^3/\text{min} \cdot 24\ \textit{Pa}}{60 \cdot 0.49} = 8W$$

The flow rate and the fan pressure (also referred to as the head), have been determined in the previous section. The constant 1/60 converts m^3/min to m^3/s so that the final answer is in watts.

The efficiency of your air-distribution fan depends on a number of factors. The main ones are the air temperature,the head against which the fan is working, the speed of rotation, and the efficiency of the drive motor itself. To simplify the calculations, it is assumed a properly sized fan can be bought for your application, so that the fan efficiency can be taken as 70%, a normal design point efficiency value for a propeller-type fan. The fan motor efficiency can be taken as 70%, again assuming the motor will be correctly sized for the work to be done. (Note that if the fan and motor are oversized or undersized, both efficiencies will be reduced, leading to higher operating costs.) The overall efficiency to be used in the power calculation above is the product of the fan and motor efficiencies, that is a 49% overall efficiency for thc values just quoted.

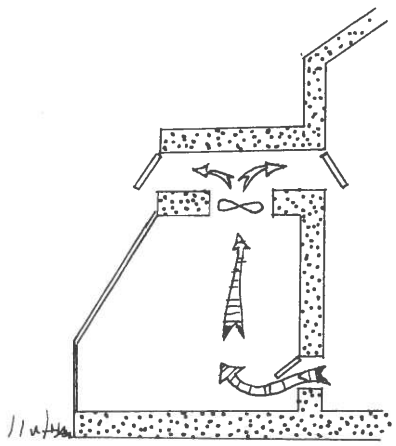
Ventilation to the Outside

On some summer days, the temperature of the air in the solarium will rise above suitable levels, yet there will be no need for additional heat in the parent building.

In a Type 1 solarium, you could simply allow overheating to occur, though this, of course, is not recommended. For Types 2 and 3, you must provide vents for the escape of the unwanted warm air. Ventilation is particularly critical if there are plants in the solarium.

The method for ventilation to the outside is similar to that for distributing air to the parent building. However, you must provide not only exhaust vents for the removal of warm air, but also return vents for its replacement by cooler air, either from the parent building or from outside. The total area of exhaust and return vents will be the same as for distribution of warm air to the parent building. All vents must have dampers, and fans may be used in the exhaust vents to accelerate ventilation.

Passive venting may simply be sliding doors or opening windows. The glazed panel which opens is itself the "damper". Passive vents, with a control which automatically opens and closes them according to the temperature inside the solarium, are avaiable from greenhouse suppliers. They are strongly preferred to ordinary windows because they adjust the open area according to the amount of ventilation required. Generally, these vent openers use special fluids, such as paraffin wax, which expand as the temperature increases.



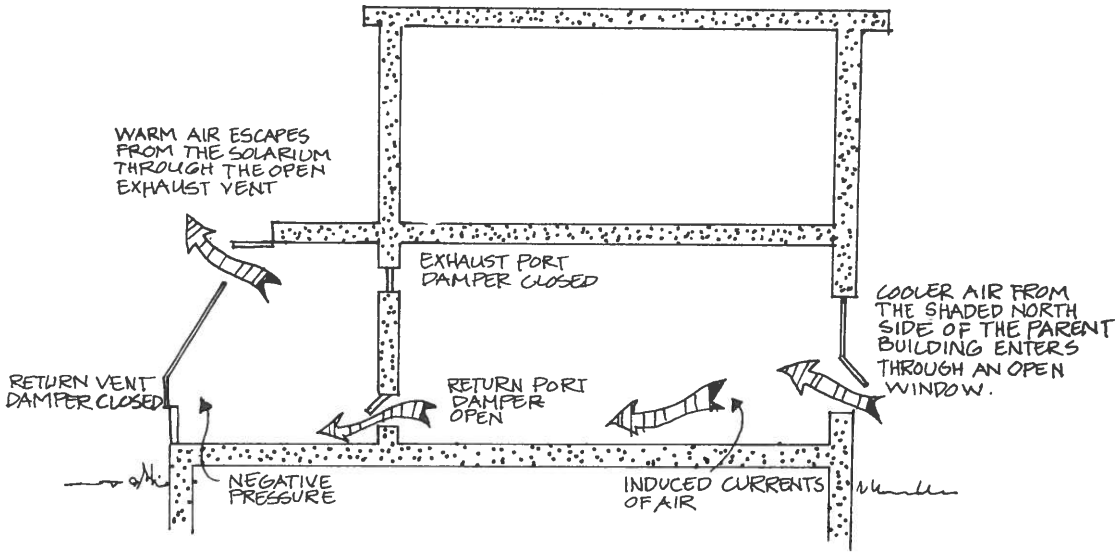
The same fan used for the distribution of air can also be used for ventilation if the installation is designed accordingly. You should provide a damper which can direct the warm air either into the parent building or to the outside. A separate fan or fans can be used for ventilation; however, the controls must be carefully set so the ventilation fans do not interfere with the air distribution fans.

The exhaust vents should be placed high and the return vents placed low. Both should be situated at opposite ends to allow circulation of air through the solarium space.

Because the vents are openings in the exterior skin of the solarium, they must be of high quality and carefully installed. It is very important that they fit tightly when closed so infiltration of cold air is kept to a minimum when they are not in use. On Types 1 and 3 it would be wise to shut these vents during the winter and to insulate them as well.

The vents should be provided with screens as well as dampers to keep out insects and birds.

While the exhaust vent must lead to the outside, the return vent also can bring air into the solarium from the parent building. This can reduce a flow of air through the parent building as well, provided some windows are open on its north side. This flow of air will help cool the parent building in the summer.


WARM AIR ESCAPES FROM THE SOLARIUM THROUGH THE OPEN EXHAUST VENT
EXHAUST PORT DAMPER CLOSED
COOLER AIR FROM THE SHADED NORTH SIDE OF THE PARENT BUILDING ENTERS THROUGH AN OPEN WINDOW.
RETURN VENT DAMPER CLOSED
RETURN PORT DAMPER OPEN
NEGATIVE PRESSURE
INDUCED CURRENTS OF AIR

Controls

Controls should be provided for equipment that may be incorporated into the solarium to allow for an exchange of air to the parent building or to the outside.

Active or Passive System? Manual or Automatic?

A distinction must be made between active or passive air movement and manual or automatic control.

Active air movement involves the use of a fan to force the air mechanically, while passive air movement occurs without a fan. Either type of air movement can be instigated and controlled manually or automatically. Automatic controls react to sensors which detect the temperatures in both the destination space and the solarium. Therefore, it is possible to operate an active system with manual controls just as it is possible to operate a passive system with automatic controls to open and close the port dampers.

The type of control system required will depend greatly upon:
- the anticipated temperature rise within the solarium;
- the sensitivity of the activities in the solarium to temperature fluctuations;
- whether the parent building is occupied during the day.

Manual Control

The simplest solaria have manual controls. If you have chosen an active system, then the fan is turned on and off with a switch. All the exhaust and return dampers, whether active or passive are opened and closed by hand. The port dampers can be hinged or sliding panels which are folded or pulled across the opening. The vents can be sliding or hinged doors, windows, or panels in the outside walls which operate like normal windows. You must read the temperature of the parent building, the solarium, and the outside air from thermometers placed in appropriate locations and adjust the dampers and fan accordingly.

Automatic Control

Automatic controls (differential thermostat, damper motors, circuitry, etc.) represent an additional expense. They also require more sophisticated dampers, particulary for vents. Costs can be reduced by keeping automatic controls to a minimum. If someone is in the parent building most of the day, a completely manual system can be considered. A reasonable option is to provide automatic controls for the distribution of air to the parent building with manual controls for ventilation, as shown in systems 1 and 2.

If automatic control is necessary, you may examine the six systems described at the end of this section, keeping in mind that the system you require may be an adaptation of one of these systems, or a combination of elements from a few. Systems 1 and 2 should be adequate for most Type 1 solaria. The addition of a supplementary heater to either of these systems will make them adequate for most Type 2 and 3 solaria. Systems 3,4,5 and 6 are considerably more sophisticated to prevent overheating in very sunny weather. But in most solaria, sun-control devices will be a much less expensive solution, and will reduce glare as well as temperature.

The basic control device for all of these systems is a differential thermostat with one sensor in the solarium and a second sensor in the destination space. The approximate temperature settings can be established according to the needs of the system, but will require "fine-tuning" to ensure the temperatures sensed by the sensors actually correspond to the conditions they are meant to represent.

Air Distribution System

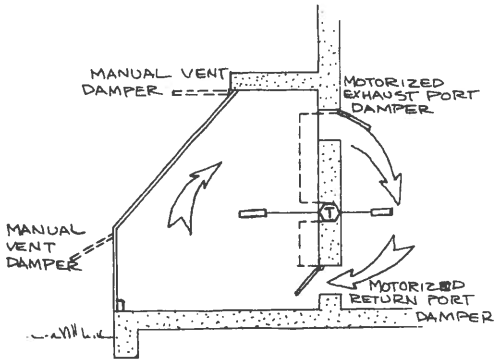
The air distribution fan (if used), exhaust port damper, and return port damper all operate simultaneously— that is, the dampers must be open while the fan is operating and closed when the fan is not operating. If the air distribution is by thermosyphon, there will be no fan, but the dampers must be either both open or both closed.

The exhaust and return port dampers can have a simple open/closed control. It is not necessary to be able to vary the size of these openings. Similarly, the distribution fan can have an on/off control. Variable speed is optional.

Ventilation System

When a ventilating fan is on, both the exhaust vent damper and the return vent damper must be open. However, both dampers may be left open while the fan is off, if they are open simply to provide fresh air, or if the need for ventilation is small.

The exhaust and return vents should have dampers which permit the size of the vent opening to be varied according to the temperature conditions inside and outside the solarium. This is critically important for a solarium where cultivation of plants is a priority. In such cases, the ventilation fan should also have variable speed. Adequate sun-control devices also will help reduce the need for ventilation.



Typical Control Systems

System 1: Passive air distribution with automatic control and passive ventilation with manual control

The differential thermostat opens the port dampers whenever the temperature in the solarium is greater than the temperature in the destination space. It closes the port dampers whenever the temperature in the solarium drops below the temperature in the destination space.

This system is adequate for Type 1 and Type 3 solaria with ports sufficiently large to operate by thermosyphon.

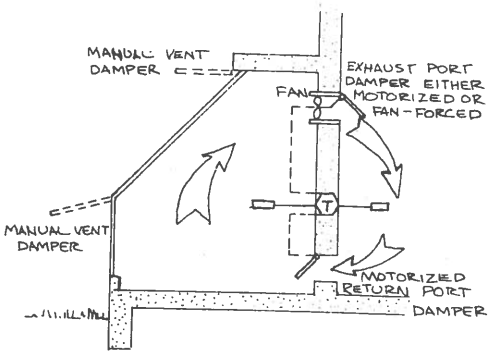
System 2: Active air distribution with automatic control and passive ventilation with manual control

The differential thermostat opens the port dampers and the fan starts whenever the temperature in the solarium is greater than the temperature in the destination space. It closes the port dampers and turns off the fan whenever the temperature in the solarium drops below that in the destination space.

The thermostat may have an override control which can be set to close off the fan and port dampers automatically. This occurs despite high temperatures in the solarium, if the temperature of the destination space should exceed a predetermined maximum acceptable temperature such as 25°C. This will protect the parent building from being overheated by the solarium on a very sunny day. The solarium will tend to overheat, but it can be vented manually.

Without such an override system, the fan and port dampers must be manually shut off for the summer to prevent the solarium from heating the parent building.

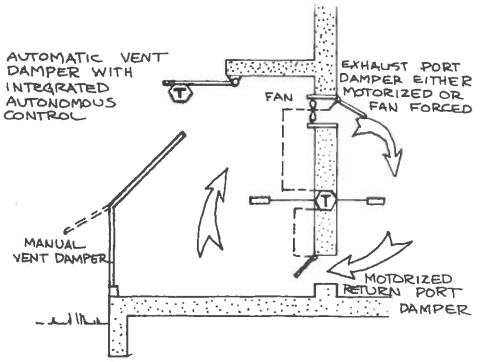
This system is adequate for Type 2 and 3 solaria.



System 3: Active air distribution with automatic control and passive ventilation with emergency automatic control

The fan and the port dampers are controlled as in system 2.

The automatic vent operates independently from the fan and port dampers, guided by its own sensing mechanism. If the temperature in the solarium exceeds a predetermined temperature, the vent will open and allow the hot air to escape to the outside. While such a vent can be used to protect the solarium from overheating in the summer, it must be manually fixed shut during the winter. A solarium with this type of control system must simply be allowed to overheat except in winter, when the heat can be transferred into the parent building.



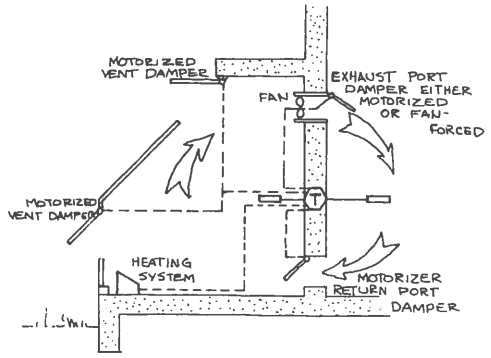
System 4: Active air distribution with automatic control and passive ventilation with automatic control

The fan and the dampers on the ports are controlled as in system 2, including the override control which shuts the port dampers and the fan if the temperature of the destination space is warm enough.

The thermostat also opens the vent dampers whenever the temperature of the solarium exceeds a predetermined maximum temperature. It simultaneously shuts the fan and port dampers to avoid the infiltration of cold air or exfiltration of warm air encountered with the autonomous vent used in system 3.

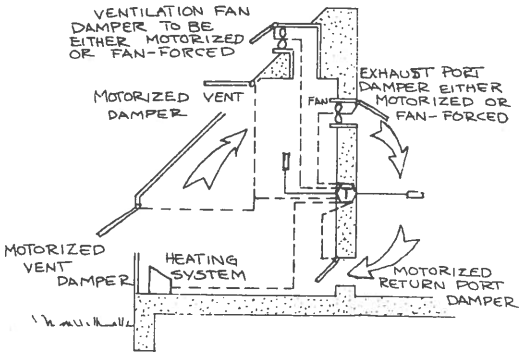
The thermostat turns on the heating system whenever the temperature of the solarium drops below a predetermined minimum temperature. (It simultaneously closes the vent dampers.) Note that if the solarium heating system is an extension of the parent building heating system, any automatic controls must be carefully set so the heating system cannot be heating the solarium at the same time as the vent dampers are open.

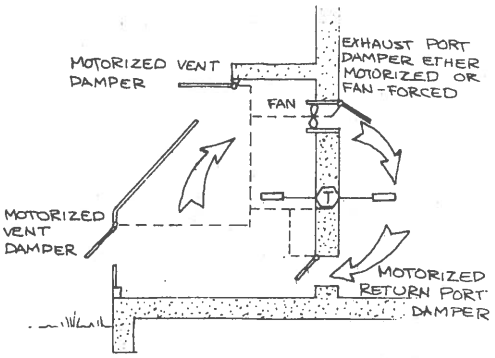
This system is appropriate for Type 2 solaria which require fully automatic control.



System 5: Active air distribution with automatic control and passive or active ventilation with automatic control

This system operates as system 4, except the thermostat will also turn on the ventilation fan whenever a predetermined maximum temperature is reached in the solarium. (This temperature will be warmer than that at which the passive vent dampers are opened.)





This system is appropriate for Type 2 solaria where a very strict control of temperatures is required automatically, such as a greenhouse.

System 6: Active air distribution with automatic control, passive ventilation with automatic control, and parent-building air used as supplementary heating for solarium

The thermostat opens the port dampers and fan to bring warm air from the solarium to heat the destination space, or to bring warm air from the parent building to heat the solarium. The temperature conditions in both spaces and the predetermined maximum and minimum temperatures for both spaces are the criteria used.

It also opens the vent dampers, as required, to ventilate the solarium, simultaneously closing the port dampers and fan.

The temperature settings must be carefully established in order to avoid conflicts between the various functions. The thermostat, sensors and circuitry required are not exorbitantly expensive.

This system is appropriate for Type 2 solaria which require fully automatic control.

Humidification

The combination of air temperature, velocity and moisture content in a given space will determine the degree of comfort of the occupants. Most people are comfortable within certain ranges of combinations. Ideal combinations vary for different activities and types of clothing.

As a general rule, most people will feel comfortable if the air temperature is close to 21°C and the relative humidity is between 40% and 80%. Most people dislike an indoor draft.

In most places in Canada, the relative humidity remains far below 40% in winter unless moisture is added to the air artificially. The Type 2 solarium solves this problem when it is used as a greenhouse. Leafy, green plants, especially, provide moisture for the air.

Humidity from circulated solarium air is particularly welcome where there are only localized heating devices. Electric baseboard heaters, hot-water radiators, etc., do not move air, with poor distribution of humidity the usual result.

Electrical and Mechanical Equipment

Moisture and temperature variations in solaria will be factors to consider when selecting mechanical and electrical equipment. Domestic fans, for example, are generally not designed to operate under the above moisture and temperature conditions; so select one that can handle these conditions. Make sure, as well, they are installed in accordance with the appropriate electrical code — especially that they are property grounded.

A solarium will need duplex receptacles, lights and possibly a special-purpose electric service. Remember such installations must be inspected and approved by a local authority.

Metal components and the high humidity in solaria are potential hazards with electricity. Specialized skill and knowledge are therefore mandatory in the installation and maintenance of electrical equipment.

The installation of ducting and piping involves more than the usual amount of handyman skill and may require the services of a sheet metal worker or plumber. Plumbing pipes and fixtures must not freeze.

Auxiliary Heating

If you wish to use your solarium when it is cold, you will probably need a heating system and fitted insulating curtains.

Central Heating System

If the parent building has a central heating system, you may be able to extend this system to heat the solarium. If the central system distributes heat by forced air, you will need to install new ductwork from the existing system to new hot-air registers and return grills in the solarium. If heating is by hot water, you will need to install new water pipes. In either case, the furnace manufacturer should be consulted to ensure:

- the furance has sufficient capacity;
- the radiators or registers are appropriate for the solarium application;
- the controls are adequate; and
- the placement of the new registers, grills and radiators will provide a properly balanced overall system.

If the solarium is to be heated intermittently, the piping and radiator system must be provided with isolating and drain valves to prevent freezing.

Independent Heaters

A heat source may be provided which is independent of the heating system in the parent building. Many options exist: electrical baseboard heaters, wood stoves, fireplaces or small portable heaters.

The heater should be selected for its ability to maintain a comfortable inside temperature under most cold-weather conditions — that is, conditions which are occasionally, but not greatly, exceeded. Accordingly, the table below lists the design temperatures for 14 Canadian cities.

The heater power rating is determined by multiplying the temperature difference by the highest *UA* value. The temperature difference is calculated by subtracting the design temperature t_d from the average temperature t_i required inside the solarium.

The highest of the *UA* values (daytime or nighttime) should be used, as this will be the most severe operating condition. Thus, if insulating blinds are used at night, the daytime *UA* value (*UAI*) should be used in the heater-sizing calculations. (In this case, the heater would be large enough to maintain a comfortable inside temperature at night even when insulating blinds are not in use.)

The heater power rating P in watts is therefore given by:

$P = (t_i - t_d) \times UA$ max

To obtain the operating cost of the heater, multiply the power rating by the operating time to obtain kWh of energy use, and multiply that figure by the cost of electricity.

Note: The heater should be controlled by a thermostat inside the solarium, or by one incorporated into the heater.

Design Temperature t_d

°C	
-7	Vancouver, B.C.
-32	Edmonton, Alta.
-30	Lethbridge, Alta.
-32	Swift Current, Sask.
-33	Winnipeg, Man.
-39	Churchill, Man.
-18	Toronto, Ont.
-25	Ottawa, Ont.
-23	Montreal, Que.
-24	Fredericton, N.B.
-22	Moncton, N.B.
-16	Halifax, N.S.
-20	Charlottetown, P.E.I.
-14	St. John's, Nfld.

Parent-Building Air

The circulation of air which normally brings heat from the solarium to the parent building can also be reversed. The thermostat in the solarium should be capable of turning the fan on when the solarium is too cold as well as when it is too hot. This arrangement has three important advantages:

– There is not the additional cost for the solarium heating system,
– Circulation of air is maintained in the solarium during very cold periods, which will help prevent the build-up of condensation.
– If you lower the settings of the thermostats in the parent building at night, there will actually be a surplus of heat in the parent building from the moment the thermostat has been set back until the parent building has cooled off. By drawing warm air into the solarium, some of this surplus heat may be recuperated.

Note: The fan will not have to operate in reverse, since the drawing of cold air from the solarium will cause the warm air from the parent building to move back into the solarium.

It must be remembered, however, that:

– this arrangement will put an additional load on the existing furnace, which must have the necessary capacity to meet this demand;

– the fan(s) and return port(s) are usually designed to provide a volume of air movement appropriate to the amount of solar energy which will be collected in the solarium and transferred to the parent building during the day. If the night-time heat requirement of the solarium is such that a much greater volume of air flow is required to keep the solarium warm, then this fan and return port will be inadequate. It is, therefore, imperative that heat loss from the solarium be limited as much as possible.

Detailed Estimate of Construction Cost

The preliminary cost estimate of Chpater 4 will serve only as an indication of your solarium's eventual cost. For the do-it-yourselfer the detailed estimate will first require a list of all the items along with the quantities needed, adding, where applicable, an allowance of about 10% for breakage and wastage. Then you should establish the best prices for these items by checking with a few local suppliers. Other costs like the transport of concrete and jobs requiring qualified tradesmen should then be evaluated to arrive at the final estimate.

If a general contractor is to build your solarium do not be too surprised by some differences between your preliminary estimate and his detailed one. First of all, his overhead and profit will probably add on at least 25%. Then there are many other variables: the location, time of year, union rates, availability of materials and labour, the size of the job and the amount of construction activity in the area. The best advice is to shop around a little to get the best deal; offers made by one contractor overloaded with work and by another needing some can differ substantially.

CHAPTER 7
FURTHER INFORMATION

Contracts

If you are not undertaking the work yourself, then you must ensure that an appropriate contract is prepared for the protection of all parties concerned. The contract should be clearly written and include the following:

(a) description, scope and content of the work to be performed by the contractor with due reference to sketches, drawings and other documents which must be clearly identified;

(b) description, scope and content of the work to be performed by any person other than the contractor named in a particular contract with a clear definition of who shall have what ready and when;

(c) specifications and/or the grade of materials, equipment, and workmanship;

(d) if both design and construction are to be carried out by the contractor, then the design brief should be designated rather than the design;

(e) statement concerning responsibility of the contractor in respect of obtaining the necessary permits, and who shall pay for them;

(f) statement concerning the maintenance of necessary insurance coverage by the contractor in respect of the work and for public liability and property damage, and for other forms of applicable insurance;

(g) statement concerning reasonable commencement and completion dates;

(h) guarantees;

(i) amount of contract and terms of payment.

Local construction associations are usually prepared to supply various types of contract forms and the names of suitable contractors. Before hiring a contractor, you should verify his competence and performance by independent enquiries. If only a portion of the work is to be carried out by a contractor, the extent of this work and the time and conditions of its execution must be very clearly defined.

It should be pointed out that the contractor also requires certain rights under a contract and that failure to observe these rights can result in extra charges. For example, if you wish to change anything after awarding the contract, you must establish with the contractor, in writing, what these changes are and what they will cost or what the rebate may be.

When the contractor arrives at the site, he must not be impeded in his work by any action or lack thereof by the owner or by another contractor. Moreover, if a contractor is to carry out an installation which depends upon prior work by another contractor or by you (e.g. foundations), then it is your responsibility to ensure that this prior work has been properly completed, that it is dimensionally correct, and is in a condition to permit further work.

You should inspect the work periodically during the course of construction. You should also examine the completed installation to ensure that it is in conformity with the contract before paying the contractor.

Suppliers of Materials, Equipment and Services

Most materials and equipment for the execution of this sort of project can be obtained from:

- building supply firms
- greenhouse manufacturers
- glazing supply firms
- hardware stores

Installation will be performed by contractors who are designated under the particular speciality required.

The names of qualified architects and engineers may be obtained from the yellow pages or from provincial architectural or engineering associations.

The use of recycled materials can often provide considerable savings. In particular, the sealed double-glass units can often be recovered from windows which are being replaced.

APPENDIX

Tabular Data for the Performance and Economic Calculations

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TABLE A-1 HEAT TRANSFER COEFFICIENT "U" FOR VARIOUS GLAZINGS IN WATTS PER SQUARE METRE PER DEGREE CELSIUS (winter conditions)

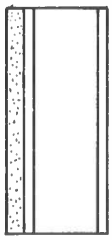
GLAZING	THICKNESS (mm) (1)	NUMBER OF PANES (2)	AIR SPACE (mm) (3)	U ($W/m^2.^oC$)
Glass Pane	5	1	-	6.4
Glass Pane	5	2	6	3.7
Glass Pane	5	2	13	3.3
Plexiglass Sheet (acrylic)	5	1	-	5.7
Plexiglass Sheet (acrylic)	6	1	-	5.5
Plexiglass Sheet (acrylic)	5	2	6	3.0
Plexiglass Sheet (acrylic)	6	2	6	2.8
Plexiglass Sheet (acrylic)	5	2	13	2.6
Plexiglass Sheet (acylic)	6	2	13	2.4
Plastic Film	0.10	1	-	6.7
Plastic Film	0.10	2	13	3.5
Fiberglass Reinforced Plastic (FRP) Sheet (flat)	1.00	1	-	4.1
FRP Sheet (flat)	1.00	2	13	3.1
FRP Sheet (corrugated)	1.00	1	-	4.6
Double Wall Extruded Polycarbonate Sheet	6	1	-	3.5
Double Wall Extruded Polycarbonate Sheet	16	1	-	3.3
Double Wall Extruded Acrylic Sheet	16	1	-	3.3

(1) Per pane
(2) Sheets or films
(3) Between two panes

TABLE A-2 HEAT TRANSFER COEFFICIENT "U" FOR VARIOUS BUILDING SECTIONS IN WATTS PER SQUARE METRE PER DEGREE CELSIUS (WINTER CONDITIONS)*

SECTION: Frame Wall

CONSTRUCTION: stucco - plywood or lumber sheathing - drywall or gypsum lath & plaster

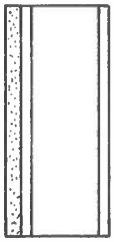


UNINSULATED U VALUE = 1.77

MATERIAL & THICK. (mm)		25	38	51	64	76	89	95
U ($W/(m^2.{}^oC)$)	rock wool, batts	0.87	0.71	0.61		0.49	0.43	
	rock wool, loose					0.52	0.49	
	glass fibre, batts			0.67	0.59	0.53	0.52	
	glass fibre, loose						0.57	0.55
	cellulose fibre						0.45	0.43
	polystyrene, loose						0.46	0.44
	urea formaldehyde						0.37	0.34
	vermiculite						0.63	0.60
	wood shavings						0.57	0.55

SECTION: Frame Wall

CONSTRUCTION: stucco - insulated sheathing - drywall or gypsum lath & plaster
or
wood or aluminum siding - plywood sheathing - drywall



UNINSULATED U VALUE = 1.58

MATERIAL & THICK. (mm)		25	38	51	64	76	89	95
U ($W/(m^2.{}^oC)$)	rock wool, batts	0.82	0.68	0.59		0.47	0.42	
	rock wool, loose						0.50	0.48
	glass fibre, batts			0.64	0.57	0.51	0.50	
	glass fibre, loose						0.55	0.53
	cellulose fibre						0.43	0.42
	polystyrene, loose						0.44	0.43
	urea formaldehyde						0.36	0.34
	vermiculite						0.60	0.57
	wood shavings						0.55	0.55

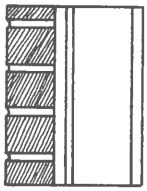
* Adapted from: Les Economies d'Energie dans l'Habitation, Société Centrale d'Hypothèques et de Logement, Gouvernement du Canada, Publication LHN 5149, (1977).

TABLE A-3 HEAT TRANSFER COEFFICIENT "U" FOR VARIOUS BUILDING SECTIONS IN WATTS PER SQUARE METRE PER DEGREE CELSIUS (WINTER CONDITIONS)*

SECTION: Frame Wall

CONSTRUCTION: wood or aluminum siding or stucco - lumber or plywood sheathing - drywall or gypsum lath & plaster

brick - air space - plywood sheathing - drywall



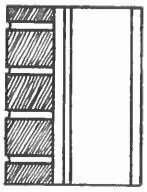
UNINSULATED U VALUE = 1.32

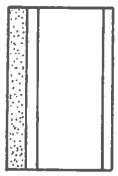
MATERIAL & THICK. (mm)		25	38	51	64	76	89	95
U ($W/(m^2.^oC)$)	rock wool, batts	0.75	0.62	0.55		0.44	0.40	
	rock wool, loose						0.47	0.45
	glass fibre, batts			0.59	0.53	0.48	0.47	
	glass fibre, loose						0.51	0.49
	cellulose fibre						0.41	0.40
	polystyrene, loose						0.42	0.41
	urea formaldehyde						0.34	0.32
	vermiculite						0.56	0.54
	wood shavings						0.51	0.49

SECTION: Frame Wall

CONSTRUCTION: Brick - air space - insulated sheathing or lumber sheathing - drywall or gypsum lath and plaster

stucco - insulated sheathing - insulated lath & plaster





UNINSULATED U VALUE = 1.21

MATERIAL & THICK. (mm)		25	38	51	64	76	89	95
U ($W/(m^2.^oC)$)	rock wool, batts	0.71	0.60	0.53		0.43	0.36	
	rock wool, loose						0.45	0.44
	glass fibre, batts			0.57	0.51	0.47	0.45	
	glass fibre, loose						0.49	0.48
	cellulose fibre						0.40	0.39
	polystyrene, loose						0.40	0.39
	urea formaldehyde						0.33	0.32
	vermiculite						0.54	0.52
	wood shavings						0.49	0.48

* Adapted from: Les Economies d'Energie dans l'Habitation, Société Centrale d'Hypothèques et de Logement, Gouvernement du Canada, Publication LHN 5149, (1977).

TABLE A-4 HEAT TRANSFER COEFFICIENT "U" FOR VARIOUS BUILDING SECTIONS IN WATTS PER SQUARE METRE PER DEGREE CELSIUS (WINTER CONDITIONS)*

SECTION: Frame Wall

CONSTRUCTION: wood or aluminum siding - lumber sheathing both sides - gypsum & plaster

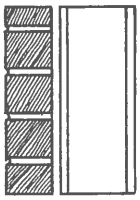
wood or aluminum - lumber sheathing - insulated lath & plaster

UNINSULATED U VALUE = 1.11

MATERIAL & THICK. (mm)		25	38	51	64	76	89	95
U (W/(m^2.^{o}C))	rock wool, batts	0.68	0.57	0.51		0.42	0.38	
	rock wool, loose						0.44	0.42
	glass fibre, batts			0.55	0.49	0.45	0.44	
	glass fibre, loose						0.48	0.46
	cellulose fibre						0.39	0.38
	polystyrene, loose						0.40	0.38
	urea formaldehyde						0.33	0.31
	vermiculite						0.52	0.50
	wood shavings						0.48	0.46

SECTION: Frame Wall

CONSTRUCTION: brick - air space - lumber or insulated sheathing - insulated lath & plaster



UNINSULATED U VALUE = 0.98

MATERIAL & THICK. (mm)		25	38	51	64	76	89	95
U (W/(m^2.^{o}C))	rock wool, batts	0.62	0.54	0.48		0.40	0.36	
	rock wool, loose						0.42	0.40
	glass fibre, batts				0.51	0.47	0.43	0.42
	glass fibre, loose						0.45	0.44
	cellulose fibre						0.37	0.36
	polystyrene, loose						0.38	0.37
	urea formaldehyde						0.31	0.30
	vermiculite						0.49	0.47
	wood shavings						0.45	0.44

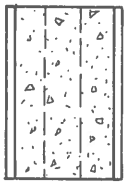
* Adapted from: Les Economies d'Energie dans l'Habitation, Société Centrale d'Hypothèques et de Logement, Gouvernement du Canada, Publication LHN 5149, (1977).

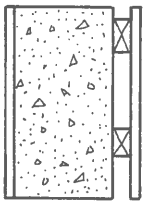
TABLE A-5 HEAT TRANSFER COEFFICIENT "U" FOR VARIOUS BUILDING SECTIONS IN WATTS PER SQUARE METRE PER DEGREE CELSIUS (WINTER CONDITIONS)*

SECTION: Concrete Wall

CONSTRUCTION: 200 mm. concrete block - 10 mm. plaster

200 mm. concrete - furring - metal lath & plaster





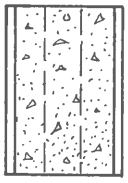
UNINSULATED U VALUE = 2.37

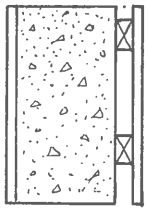
MATERIAL & THICK. (mm)		38	64	89				
U (W/(m^2.^{o}C))	rock wool, batts	0.81	0.58	0.46				
	rock wool, loose	0.87	0.62	0.51				
	glass fibre, batts							
	glass fibre, loose							
	cellulose fibre							
	polystyrene, loose							
	urea formaldehyde							
	vermiculite							
	wood shavings							

SECTION: Concrete or Masonry Wall

CONSTRUCTION: 200 mm. hollow clay tile or 300 mm. cinder block - 15 mm.

200 mm. concrete - furring - gypsum lath & plaster





UNINSULATED U VALUE = 2.03

MATERIAL & THICK. (mm)		38	64	89				
U (W/(m^2.^{o}C))	rock wool, batts	0.77	0.56	0.45				
	rock wool, loose	0.82	0.60	0.49				
	glass fibre, batts							
	glass fibre, loose							
	cellulose fibre							
	polystyrene, loose							
	urea formaldehyde							
	vermiculite							
	wood shavings							

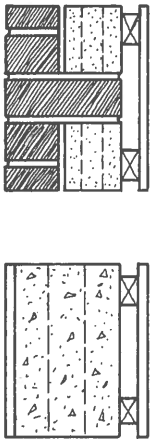
* Adapted from: Les Economies d'Energie dans l'Habitation, Société Centrale d'Hypothèques et de Logement, Gouvernement du Canada, Publication LHN 5149, (1977).

TABLE A-6 HEAT TRANSFER COEFFICIENT "U" FOR VARIOUS BUILDING SECTIONS IN WATTS PER SQUARE METRE PER DEGREE CELSIUS (WINTER CONDITIONS)*

SECTION: Concrete or Masonry Wall

CONSTRUCTION: 100 mm. face brick - 100 mm. common brick or 100 mm. concrete block - furring - gypsum lath or metal lath & plaster or drywall

300 mm. concrete block - furring - gypsum lath & plaster or drywall



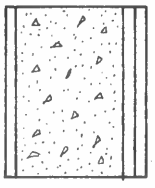
UNINSULATED U VALUE = 1.67

U (W/(m^2.°C)) MATERIAL & THICK. (mm)	38	64	89				
rock wool, batts	0.71	0.53	0.43				
rock wool, loose	0.76	0.56	0.47				
glass fibre, batts							
glass fibre, loose							
cellulose fibre							
polystyrene, loose							
urea formaldehyde							
vermiculite							
wood shavings							

SECTION: Concrete Wall

CONSTRUCTION: 200 mm. concrete - furring - insulated lath & plaster or drywall

200 mm. hollow clay tile - furring - gypsum lath & plaster or drywall



UNINSULATED U VALUE = 1.42

U (W/(m^2.°C)) MATERIAL & THICK. (mm)	38	64	89				
rock wool, batts	0.66	0.50	0.41				
rock wool, loose	0.70	0.53	0.44				
glass fibre, batts							
glass fibre, loose							
cellulose fibre							
polystyrene, loose							
urea formaldehyde							
vermiculite							
wood shavings							

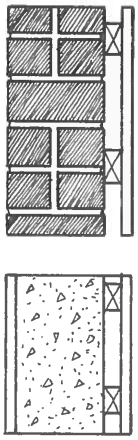
* Adapted from: Les Economies d'Energie dans l'Habitation, Société Centrale d'Hypothèques et de Logement, Gouvernement du Canada, Publication LHN 5149, (1977).

TABLE A-7 HEAT TRANSFER COEFFICIENT "U" FOR VARIOUS BUILDING SECTIONS IN WATTS PER SQUARE METRE PER DEGREE CELSIUS (WINTER CONDITIONS)*

SECTION: Concrete or Masonry Wall

CONSTRUCTION: 100 mm. face brick - 100 mm. common brick - furring - insulated lath & plaster or drywall

300 mm. concrete block - furring - insulated lath & plaster or drywall



UNINSULATED U VALUE = 1.23

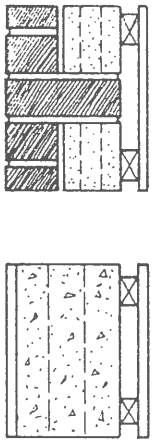
MATERIAL & THICK. (mm)		38	64	89				
U ($W/(m^2.^oC)$)	rock wool, batts	0.62	0.47	0.38				
	rock wool, loose	0.65	0.50	0.41				
	glass fibre, batts							
	glass fibre, loose							
	cellulose fibre							
	polystyrene, loose							
	urea formaldehyde							
	vermiculite							
	wood shavings							

SECTION: Concrete and Masonry Wall

CONSTRUCTION: 100 mm. face brick - 100 mm. concrete block - furring - insulated lath or foil-backed gypsum & plaster

or

300 mm. cinder block - furring - insulated lath & plaster



UNINSULATED U VALUE = 1.09

MATERIAL & THICK. (mm)		38	64	89				
U ($W/(m^2.^oC)$)	rock wool, batts	0.58	0.45	0.37				
	rock wool, loose	0.61	0.48	0.39				
	glass fibre, batts							
	glass fibre, loose							
	cellulose fibre							
	polystyrene, loose							
	urea formaldehyde							
	vermiculite							
	wood shavings							

* Adapted from: Les Economies d'Energie dans l'Habitation, Société Centrale d'Hypothèques et de Logement, Gouvernement du Canada, Publication LHN 5149, (1977).

TABLE A-8 HEAT TRANSFER COEFFICIENT "U" FOR VARIOUS BUILDING SECTIONS IN WATTS PER SQUARE METRE PER DEGREE CELSIUS (WINTER CONDITIONS)*

SECTION: Frame Roofs

CONSTRUCTION: vented space - joist - gypsum lath & plaster or drywall

UNINSULATED U VALUE = 4.37

MATERIAL & THICK. (mm)		51	100	150	200	250	300	
U ($W/(m^2.^oC)$)	rock wool, batts	0.78	0.43					
	rock wool, loose			0.38	0.26	0.21	0.17	
	glass fibre, batts		0.47	0.33	0.25	0.18		
	glass fibre, loose			0.38	0.30	0.24	0.20	
	cellulose fibre			0.28	0.22	0.16	0.22	
	polystyrene, loose							
	urea formaldehyde							
	vermiculite	1.00	0.61	0.43	0.34	0.27		
	wood shavings	0.95	0.55					

SECTION: Frame Roof

CONSTRUCTION: non vented space - joist - gypsum lath & plaster
or
vented space - fiberboard - plaster

UNINSULATED U VALUE = 1.83

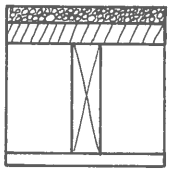
MATERIAL & THICK. (mm)		51	100	150	200	250	300	
U ($W/(m^2.^oC)$)	rock wool, batts	0.62	0.38					
	rock wool, loose			0.30	0.24	0.19	0.16	
	glass fibre, batts		0.41	0.30	0.23	0.17		
	glass fibre, loose			0.34	0.27	0.22	0.18	
	cellulose fibre			0.26	0.21	0.15	0.21	
	polystyrene, loose							
	urea formaldehyde							
	vermiculite	0.76	0.51	0.38	0.30	0.25		
	wood shavings	0.73	0.46					

* Adapted from: Les Economies d'Energie dans l'Habitation, Société Centrale d'Hypothèques et de Logement, Gouvernement du Canada, Publication LHN 5149, (1977).

TABLE A-9 HEAT TRANSFER COEFFICIENT "U" FOR VARIOUS BUILDING SECTIONS IN WATTS PER SQUARE METRE PER DEGREE CELSIUS (WINTER CONDITIONS)*

SECTION: Frame Roof

CONSTRUCTION: roofing - 25 mm. deck or 15 mm. plywood - drywall or gypsum lath & plaster



UNINSULATED U VALUE = 1.72

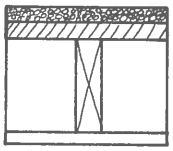
MATERIAL & THICK. (mm)		51	100	150	200	250	300	
U ($W/(m^2.{}^oC)$)	rock wool, batts	0.61	0.37					
	rock wool, loose			0.30	0.24	0.19	0.16	
	glass fibre, batts		0.40	0.29	0.23	0.17		
	glass fibre, loose			0.33	0.27	0.22	0.18	
	cellulose fibre			0.26	0.21	0.15	0.13	
	polystyrene, loose							
	urea formaldehyde							
	vermiculite	0.74	0.50	0.37	0.30	0.24	0.21	
	wood shavings	0.71	0.46					

SECTION: Frame Roof

CONSTRUCTION: roofing - 50 mm. deck - drywall, or gypsum lath & plaster

or

roofing - 25 mm. deck - insulating lath & plaster



UNINSULATED U VALUE = 1.29

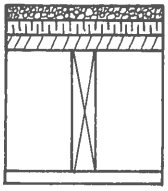
MATERIAL & THICK. (mm)		51	100	150	200	250	300	
U ($W/(m^2.{}^oC)$)	rock wool, batts	0.55	0.35					
	rock wool, loose			0.28	0.23	0.19	0.16	
	glass fibre, batts		0.37	0.28	0.22	0.17		
	glass fibre, loose			0.31	0.25	0.21		
	cellulose fibre			0.25	0.20	0.15	0.13	
	polystyrene, loose							
	urea formaldehyde							
	vermiculite	0.65	0.46	0.35	0.28	0.23	0.20	
	wood shavings	0.62	0.42					

* Adapted from: Les Economies d'Energie dans l'Habitation, Société Centrale d'Hypothèques et de Logement, Gouvernement du Canada, Publication LHN 5149, (1977).

TABLE A-10 HEAT TRANSFER COEFFICIENT "U" FOR VARIOUS BUILDING SECTIONS IN WATTS PER SQUARE METRE PER DEGREE CELSIUS (WINTER CONDITIONS)*

SECTION: Frame Roof

CONSTRUCTION: roofing - 30 mm. insulation - 25 mm. deck or 15 mm. plywood - gypsum lath & plaster or drywall

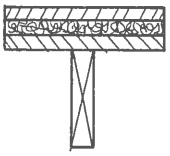


UNINSULATED U VALUE = 0.76

MATERIAL & THICK. (mm)		51	100	150	200	250	300	
U (W/(m^2.^{o}C))	rock wool, batts	0.42	0.29					
	rock wool, loose			0.25	0.20	0.17	0.14	
	glass fibre, batts		0.31	0.24	0.20	0.15		
	glass fibre, loose			0.27	0.22	0.19	0.16	
	cellulose fibre			0.22	0.18	0.14	0.12	
	polystyrene, loose							
	urea formaldehyde							
	vermiculite	0.48	0.37	0.31	0.25	0.21	0.18	
	wood shavings	0.47	0.34					

SECTION: Floor

CONSTRUCTION: carpet - underlay - 19 mm. subfloor-joist
or
floor tile - 19 mm. subfloor - joist



UNINSULATED U VALUE = 1.89

MATERIAL & THICK. (mm)		51	100	150	200	250	300	
U (W/(m^2.^{o}C))	rock wool, batts	0.60	0.38	0.28	0.22	0.18	0.15	
	rock wool, loose							
	glass fibre, batts		0.41	0.30	0.24	0.19	0.16	
	glass fibre, loose							
	cellulose fibre							
	polystyrene, loose							
	urea formaldehyde							
	vermiculite							
	wood shavings							

* Adapted from: Les Economies d'Energie dans l'Habitation, Société Centrale d'Hypothèques et de Logement, Gouvernement du Canada, Publication LHN 5149, (1977).

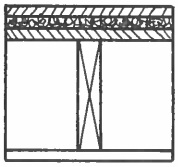
TABLE A-11 HEAT TRANSFER COEFFICIENT "U" FOR VARIOUS BUILDING SECTIONS IN WATTS PER SQUARE METRE PER DEGREE CELSIUS (WINTER CONDITIONS)*

SECTION: Floor

CONSTRUCTION: carpet - underlay - 19 mm. subfloor-joist - drywall

or

floor tile - 19 mm. subfloor - joist-drywall



UNINSULATED U VALUE = 1.26

MATERIAL & THICK. (mm)		51	100	150	200	250	300	
U ($W/(m^2.^oC)$)	rock wool, batts	0.54	0.35	0.26				
	rock wool, loose			0.28	0.23	0.19	0.16	
	glass fibre, batts		0.37	0.28				
	glass fibre, loose			0.31	0.25	0.21	0.18	
	cellulose fibre			0.24	0.20	0.16	0.13	
	polystyrene, loose							
	urea formaldehyde							
	vermiculite							
	wood shavings							

SECTION:

CONSTRUCTION:

UNINSULATED U VALUE =

MATERIAL & THICK. (mm)								
U ($W/(m^2.^oC)$)	rock wool, batts							
	rock wool, loose							
	glass fibre, batts							
	glass fibre, loose							
	cellulose fibre							
	polystyrene, loose							
	urea formaldehyde							
	vermiculite							
	wood shavings							

* Adapted from: Les Economies d'Energie dans l'Habitation, Société Centrale d'Hypothèques et de Logement, Gouvernement du Canada, Publication LHN 5149, (1977).

Table A-12 AVERAGE DAILY TRANSMITTANCE FACTORS FOR SINGLE PANE GLASS FOR CANADIAN LOCATIONS UNDER WINTER CONDITIONS.

GLAZING ORIENTATION (DEGREES FROM DUE SOUTH)	GLAZING INCLINATION (DEGREES ABOVE HORIZONTAL)						
	0	15	30	45	60	75	90
0	0.70	0.78	0.81	0.82	0.83	0.83	0.83
15	0.70	0.78	0.81	0.82	0.82	0.82	0.82
30	0.70	0.77	0.79	0.80	0.80	0.80	0.79
45	0.70	0.77	0.79	0.79	0.79	0.78	0.76
60	0.70	0.75	0.76	0.79	0.78	0.76	0.77
75	0.70	0.73	0.75	0.73	0.76	0.73	0.77
90	0.70	0.73	0.69	0.71	0.75	0.71	0.75

Note: The above transmittance factors are based on hourly weighted values taking into account solar intensity and angle of incidence. The diffuse radiation component is also included in the calculated transmittance values.

TABLE A-13 MULTIPLICATION FACTORS FOR VARIOUS GLAZINGS. THIS TABLE IS TO BE USED ONLY IN CONJUNCTION WITH TABLE A-12.

GLAZING	THICKNESS (mm)	MULTIPLICATION FACTOR
Glass Double Pane (Standard Window)	5	0.87
Acrylic Single Sheet	5	1.03
Acrylic Double Sheet	5	0.93
Polycarbonate Single Sheet	2	0.97
Polycarbonate Double Sheet	2	0.84
FRP (1) Single Sheet (High Solar Performance)	1	1.00
FRP Double Sheet (High Solar Performance)	1	0.89
FRP Single Sheet	1	0.84
FRP Double Sheet	1	0.59
Polyethylene (2) Single Film	0.10	1.02
Polyethylene Double Film	0.10	0.91
FRP Corrugated Single Sheet	1	0.91
FRP Corrugated Double Sheet	1	0.70
Double Wall Extruded Polycarbonate Sheet	6	0.77
Double Wall Extruded Polycarbonate Sheet	16	0.74
Double Wall Extruded Acrylic Sheet	16	0.83
Polyester (2) Single Film	0.12	1.00
Polyester Double Film	0.12	0.90

Note: (1) FRP - Fiberglass Reinforced Plastic

(2) Polyethylene and Polyester films have relatively high infra-red radiation transmission characteristics which make them less suitable for heat gain application than the other glazings listed.

TABLE A-14 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= VANCOUVER - BC. LATITUDE=49.25 DEG. N

******* ORIENTATION= 0 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	803	1050	1249	1386	1452	1442	1358	
FEB *	1578	1928	2189	2344	2382	2300	2104	
MAR *	2778	3154	3386	3458	3364	3111	2716	
APR *	4150	4403	4466	4329	4002	3507	2879	
MAY *	5703	5790	5654	5287	4710	3963	3105	
JUN *	6014	5978	5735	5276	4628	3835	2963	
JUL *	6394	6423	6212	5753	5071	4213	3250	
AUG *	5167	5400	5402	5164	4700	4042	3239	
SEP *	3728	4163	4402	4426	4234	3840	3270	
OCT *	2014	2415	2703	2859	2873	2743	2478	
NOV *	981	1258	1479	1626	1691	1668	1559	
DEC *	633	842	1013	1133	1196	1195	1132	

******* ORIENTATION=15 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	803	1041	1231	1362	1422	1409	1323	
FEB *	1578	1915	2164	2309	2338	2251	2053	
MAR *	2778	3141	3363	3428	3330	3076	2685	
APR *	4150	4398	4463	4336	4022	3543	2935	
MAY *	5703	5789	5661	5307	4747	4019	3182	
JUN *	6014	5980	5746	5301	4669	3893	3038	
JUL *	6394	6424	6223	5780	5117	4280	3338	
AUG *	5167	5396	5403	5178	4731	4094	3315	
SEP *	3728	4151	4385	4410	4225	3842	3288	
OCT *	2014	2399	2674	2818	2822	2686	2419	
NOV *	981	1248	1459	1599	1657	1630	1520	
DEC *	633	834	998	1113	1170	1167	1103	

******* ORIENTATION=30 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	803	1014	1181	1290	1334	1311	1222	
FEB *	1578	1877	2094	2210	2220	2121	1921	
MAR *	2778	3104	3302	3352	3250	3003	2628	
APR *	4150	4378	4443	4330	4042	3597	3031	
MAY *	5703	5786	5679	5363	4851	4177	3395	
JUN *	6014	5986	5776	5370	4783	4056	3247	
JUL *	6394	6426	6252	5854	5245	4468	3585	
AUG *	5167	5380	5400	5204	4801	4216	3496	
SEP *	3728	4111	4325	4345	4168	3806	3285	
OCT *	2014	2358	2597	2714	2700	2556	2292	
NOV *	981	1219	1402	1517	1557	1519	1405	
DEC *	633	812	955	1052	1096	1085	1018	

******* ORIENTATION=45 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	803	974	1103	1182	1204	1168	1076	
FEB *	1578	1822	1993	2077	2065	1959	1766	
MAR *	2778	3046	3205	3234	3126	2889	2539	
APR *	4150	4338	4391	4285	4020	3611	3089	
MAY *	5703	5774	5686	5412	4957	4348	3632	
JUN *	6014	5991	5815	5462	4940	4281	3535	
JUL *	6394	6423	6282	5941	5405	4706	3899	
AUG *	5167	5345	5364	5192	4831	4300	3642	
SEP *	3728	4045	4220	4226	4055	3717	3238	
OCT *	2014	2295	2487	2570	2537	2389	2138	
NOV *	981	1173	1317	1400	1417	1366	1251	
DEC *	633	778	889	959	983	959	888	

TABLE A-15 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= VANCOUVER - BC. LATITUDE=49.25 DEG. N

		******* ORIENTATION=60 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	803	924	1013	1060	1060	1015	925	
FEB	*	1578	1752	1870	1916	1883	1773	1592	
MAR	*	2778	2969	3076	3075	2959	2732	2410	
APR	*	4150	4281	4305	4195	3946	3568	3089	
MAY	*	5703	5746	5660	5414	5005	4453	3794	
JUN	*	6014	5987	5831	5520	5055	4457	3768	
JUL	*	6394	6406	6279	5980	5504	4874	4134	
AUG	*	5167	5290	5288	5125	4796	4313	3712	
SEP	*	3728	3954	4074	4053	3883	3568	3130	
OCT	*	2014	2215	2347	2392	2339	2191	1958	
NOV	*	981	1117	1216	1265	1260	1200	1090	
DEC	*	633	735	811	853	857	823	754	

		******* ORIENTATION=75 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	803	867	914	930	912	860	777	
FEB	*	1578	1670	1729	1736	1683	1570	1405	
MAR	*	2778	2875	2918	2881	2752	2534	2240	
APR	*	4150	4208	4185	4057	3813	3461	3020	
MAY	*	5703	5703	5594	5355	4976	4468	3860	
JUN	*	6014	5971	5812	5522	5096	4546	3906	
JUL	*	6394	6373	6233	5950	5516	4941	4258	
AUG	*	5167	5216	5169	4996	4683	4239	3688	
SEP	*	3728	3842	3887	3828	3649	3353	2956	
OCT	*	2014	2120	2185	2186	2113	1966	1754	
NOV	*	981	1054	1105	1120	1096	1030	928	
DEC	*	633	688	727	742	730	689	624	

		******* ORIENTATION=90 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	803	808	812	801	768	712	637	
FEB	*	1578	1581	1578	1545	1473	1360	1210	
MAR	*	2778	2771	2738	2656	2511	2301	2033	
APR	*	4150	4121	4032	3870	3621	3287	2881	
MAY	*	5703	5645	5488	5229	4860	4384	3820	
JUN	*	6014	5943	5755	5459	5050	4535	3936	
JUL	*	6394	6325	6140	5843	5425	4889	4256	
AUG	*	5167	5125	5008	4801	4489	4072	3566	
SEP	*	3728	3715	3667	3556	3361	3079	2721	
OCT	*	2014	2016	2008	1963	1870	1725	1533	
NOV	*	981	986	989	974	932	864	772	
DEC	*	633	638	642	633	608	564	505	

TABLE A-16 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= EDMONTON - ALTA. LATITUDE=53.57 DEG. N

******* ORIENTATION= 0 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN	*	1033	1705	2285	2731	3015	3117	3029
FEB	*	1961	2728	3351	3789	4010	4000	3760
MAR	*	3472	4242	4792	5086	5102	4841	4319
APR	*	4856	5298	5497	5431	5104	4537	3771
MAY	*	5733	5871	5789	5471	4931	4205	3348
JUN	*	6106	6106	5907	5488	4867	4086	3205
JUL	*	6283	6359	6210	5814	5187	4371	3431
AUG	*	5078	5372	5438	5261	4848	4228	3446
SEP	*	3519	4019	4326	4419	4290	3948	3418
OCT	*	2161	2805	3308	3634	3761	3681	3399
NOV	*	1117	1690	2175	2538	2755	2810	2701
DEC	*	750	1278	1737	2096	2330	2423	2369

******* ORIENTATION=15 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN	*	1033	1682	2239	2667	2936	3028	2937
FEB	*	1961	2700	3298	3713	3917	3897	3653
MAR	*	3472	4216	4746	5024	5032	4768	4251
APR	*	4856	5289	5491	5436	5126	4580	3838
MAY	*	5733	5869	5794	5488	4963	4254	3416
JUN	*	6106	6107	5916	5509	4903	4137	3272
JUL	*	6283	6359	6218	5835	5225	4428	3507
AUG	*	5078	5366	5437	5271	4873	4272	3511
SEP	*	3519	4006	4307	4400	4277	3946	3430
OCT	*	2161	2782	3262	3569	3682	3593	3308
NOV	*	1117	1669	2135	2482	2687	2734	2622
DEC	*	750	1259	1701	2045	2268	2354	2298

******* ORIENTATION=30 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN	*	1033	1612	2105	2477	2703	2768	2668
FEB	*	1961	2620	3146	3500	3658	3610	3359
MAR	*	3472	4144	4624	4871	4866	4608	4115
APR	*	4856	5256	5456	5421	5144	4644	3957
MAY	*	5733	5862	5805	5533	5052	4392	3604
JUN	*	6106	6109	5939	5567	5003	4281	3459
JUL	*	6283	6356	6238	5895	5333	4589	3720
AUG	*	5078	5347	5428	5290	4934	4382	3675
SEP	*	3519	3961	4239	4324	4206	3892	3405
OCT	*	2161	2716	3140	3401	3482	3376	3091
NOV	*	1117	1610	2020	2319	2487	2511	2392
DEC	*	750	1205	1596	1896	2086	2151	2087

******* ORIENTATION=45 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN	*	1033	1503	1896	2183	2345	2371	2260
FEB	*	1961	2502	2930	3208	3316	3245	3001
MAR	*	3472	4030	4434	4635	4612	4365	3911
APR	*	4856	5193	5370	5341	5094	4640	4013
MAY	*	5733	5845	5805	5576	5152	4557	3835
JUN	*	6106	6110	5971	5650	5148	4492	3731
JUL	*	6283	6349	6260	5971	5479	4810	4013
AUG	*	5078	5306	5382	5266	4950	4451	3804
SEP	*	3519	3887	4122	4187	4070	3777	3328
OCT	*	2161	2618	2965	3171	3217	3100	2829
NOV	*	1117	1517	1845	2074	2191	2185	2059
DEC	*	750	1118	1430	1661	1798	1831	1756

TABLE A-17 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= EDMONTON - ALTA. LATITUDE=53.57 DEG. N

		******* ORIENTATION=60 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1033	1370	1651	1849	1950	1944	1832	
FEB	*	1961	2353	2666	2862	2920	2834	2608	
MAR	*	3472	3879	4181	4322	4276	4041	3631	
APR	*	4856	5100	5229	5190	4961	4549	3981	
MAY	*	5733	5809	5767	5564	5187	4650	3988	
JUN	*	6106	6101	5980	5702	5258	4666	3965	
JUL	*	6283	6325	6246	5998	5566	4966	4238	
AUG	*	5078	5241	5291	5181	4894	4442	3852	
SEP	*	3519	3786	3958	3991	3869	3595	3186	
OCT	*	2161	2492	2747	2889	2900	2777	2527	
NOV	*	1117	1404	1639	1797	1865	1836	1713	
DEC	*	750	1012	1232	1390	1473	1476	1398	

		******* ORIENTATION=75 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1033	1222	1390	1504	1550	1522	1420	
FEB	*	1961	2181	2370	2481	2491	2393	2192	
MAR	*	3472	3698	3876	3943	3868	3643	3279	
APR	*	4856	4981	5035	4964	4740	4362	3849	
MAY	*	5733	5755	5684	5485	5138	4648	4040	
JUN	*	6106	6077	5949	5691	5288	4749	4101	
JUL	*	6283	6283	6185	5951	5560	5016	4349	
AUG	*	5078	5154	5151	5026	4755	4340	3803	
SEP	*	3519	3662	3751	3739	3606	3347	2977	
OCT	*	2161	2346	2496	2569	2545	2417	2194	
NOV	*	1117	1278	1417	1506	1530	1485	1372	
DEC	*	750	896	1025	1114	1152	1134	1061	

		******* ORIENTATION=90 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1033	1068	1128	1169	1172	1130	1043	
FEB	*	1961	1996	2055	2084	2051	1947	1774	
MAR	*	3472	3495	3529	3512	3403	3187	2869	
APR	*	4856	4841	4791	4666	4433	4081	3619	
MAY	*	5733	5684	5555	5333	4996	4540	3982	
JUN	*	6106	6040	5874	5607	5225	4724	4123	
JUL	*	6283	6223	6072	5821	5448	4946	4333	
AUG	*	5078	5049	4965	4802	4530	4143	3654	
SEP	*	3519	3521	3509	3440	3287	3041	2709	
OCT	*	2161	2186	2224	2227	2169	2040	1844	
NOV	*	1117	1144	1190	1217	1205	1150	1053	
DEC	*	750	777	822	853	855	824	760	

TABLE A-18 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= LETHBRIDGE - ALTA. LATITUDE=49.63 DEG. N

******* ORIENTATION= 0 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	1394	2101	2696	3139	3397	3456	3309	
FEB *	2442	3261	3909	4341	4528	4456	4131	
MAR *	3953	4708	5220	5455	5396	5048	4434	
APR *	4883	5238	5355	5220	4842	4246	3477	
MAY *	6047	6153	6018	5633	5020	4221	3299	
JUN *	6744	6713	6445	5928	5189	4279	3276	
JUL *	7094	7143	6919	6411	5643	4671	3574	
AUG *	6047	6377	6419	6162	5618	4825	3843	
SEP *	4303	4896	5244	5323	5127	4670	3982	
OCT *	2792	3554	4132	4488	4596	4449	4058	
NOV *	1628	2363	2973	3416	3662	3694	3509	
DEC *	1047	1595	2060	2410	2621	2678	2578	

******* ORIENTATION=15 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	1394	2076	2648	3070	3313	3362	3212	
FEB *	2442	3231	3851	4259	4427	4344	4015	
MAR *	3953	4682	5174	5396	5329	4980	4373	
APR *	4883	5231	5351	5228	4868	4294	3551	
MAY *	6047	6152	6025	5655	5061	4283	3383	
JUN *	6744	6716	6458	5958	5238	4350	3367	
JUL *	7094	7144	6932	6442	5698	4751	3680	
AUG *	6047	6371	6421	6180	5658	4893	3943	
SEP *	4303	4879	5222	5303	5115	4672	4006	
OCT *	2792	3525	4078	4411	4501	4344	3948	
NOV *	1628	2337	2922	3344	3574	3595	3407	
DEC *	1047	1576	2023	2357	2555	2605	2503	

******* ORIENTATION=30 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	1394	2002	2505	2868	3066	3086	2926	
FEB *	2442	3146	3689	4034	4155	4045	3712	
MAR *	3953	4610	5055	5248	5173	4835	4260	
APR *	4883	5203	5324	5220	4893	4366	3677	
MAY *	6047	6148	6045	5716	5174	4455	3617	
JUN *	6744	6722	6495	6041	5377	4548	3621	
JUL *	7094	7145	6967	6530	5851	4975	3974	
AUG *	6047	6349	6415	6214	5750	5055	4182	
SEP *	4303	4826	5141	5215	5038	4622	4000	
OCT *	2792	3448	3935	4216	4272	4099	3708	
NOV *	1628	2259	2773	3133	3315	3307	3108	
DEC *	1047	1519	1912	2201	2364	2392	2282	

******* ORIENTATION=45 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	1394	1888	2288	2564	2699	2681	2514	
FEB *	2442	3018	3459	3726	3799	3671	3352	
MAR *	3953	4497	4866	5017	4930	4611	4084	
APR *	4883	5150	5253	5159	4862	4382	3753	
MAY *	6047	6134	6052	5770	5292	4645	3879	
JUN *	6744	6728	6542	6153	5568	4822	3972	
JUL *	7094	7142	7002	6634	6043	5261	4351	
AUG *	6047	6302	6366	6197	5788	5165	4374	
SEP *	4303	4737	5001	5055	4886	4502	3933	
OCT *	2792	3331	3728	3946	3966	3786	3420	
NOV *	1628	2142	2552	2827	2948	2907	2705	
DEC *	1047	1429	1740	1959	2070	2066	1946	

TABLE A-19 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= LETHBRIDGE - ALTA. LATITUDE=49.63 DEG. N

		******* ORIENTATION=60 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1394	1747	2032	2219	2294	2249	2089	
FEB	*	2442	2857	3176	3358	3382	3243	2952	
MAR	*	3953	4346	4614	4707	4604	4304	3830	
APR	*	4883	5072	5136	5036	4761	4322	3750	
MAY	*	6047	6102	6022	5771	5343	4759	4057	
JUN	*	6744	6723	6560	6223	5707	5036	4257	
JUL	*	7094	7121	6996	6679	6160	5462	4633	
AUG	*	6047	6228	6263	6105	5739	5179	4465	
SEP	*	4303	4616	4805	4823	4653	4299	3787	
OCT	*	2792	3180	3468	3613	3596	3415	3081	
NOV	*	1628	1996	2289	2476	2540	2475	2285	
DEC	*	1047	1319	1538	1684	1744	1715	1597	

		******* ORIENTATION=75 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1394	1589	1754	1855	1877	1814	1670	
FEB	*	2442	2670	2854	2945	2922	2778	2520	
MAR	*	3953	4164	4308	4329	4200	3917	3496	
APR	*	4883	4972	4973	4848	4581	4175	3654	
MAY	*	6047	6053	5947	5703	5309	4774	4129	
JUN	*	6744	6702	6536	6224	5756	5145	4425	
JUL	*	7094	7079	6939	6642	6172	5540	4781	
AUG	*	6047	6127	6102	5930	5586	5077	4430	
SEP	*	4303	4467	4555	4521	4340	4012	3552	
OCT	*	2792	3004	3166	3230	3175	2994	2698	
NOV	*	1628	1831	2001	2100	2113	2032	1862	
DEC	*	1047	1196	1321	1398	1415	1368	1261	

		******* ORIENTATION=90 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1394	1422	1469	1492	1471	1399	1276	
FEB	*	2442	2467	2507	2508	2441	2296	2074	
MAR	*	3953	3961	3957	3892	3731	3462	3093	
APR	*	4883	4854	4766	4594	4320	3939	3466	
MAY	*	6047	5988	5827	5561	5178	4678	4082	
JUN	*	6744	6667	6464	6144	5698	5129	4460	
JUL	*	7094	7020	6825	6510	6060	5475	4777	
AUG	*	6047	6005	5885	5666	5323	4851	4264	
SEP	*	4303	4296	4261	4157	3954	3644	3236	
OCT	*	2792	2811	2834	2814	2721	2543	2286	
NOV	*	1628	1655	1701	1720	1689	1600	1456	
DEC	*	1047	1068	1103	1118	1100	1044	952	

TABLE A-20 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= SWIFT CURRENT - SASK. LATITUDE=50.27 DEG. N

******* ORIENTATION= 0 DEGREES OFF DUE SOUTH *******

INCLINATION=	*	0	15	30	45	60	75	90	DEGREES
JAN	*	1406	2170	2818	3304	3595	3671	3527	
FEB	*	2453	3327	4024	4496	4710	4653	4328	
MAR	*	4008	4817	5375	5643	5604	5260	4634	
APR	*	4917	5291	5424	5300	4927	4330	3553	
MAY	*	5917	6025	5900	5531	4939	4164	3268	
JUN	*	6381	6355	6109	5631	4945	4099	3164	
JUL	*	6833	6884	6677	6198	5471	4547	3501	
AUG	*	5633	5930	5966	5729	5232	4509	3614	
SEP	*	4006	4537	4847	4913	4731	4313	3687	
OCT	*	2625	3340	3884	4220	4325	4191	3829	
NOV	*	1453	2091	2621	3005	3218	3245	3084	
DEC	*	1081	1713	2254	2666	2921	3002	2903	

******* ORIENTATION=15 DEGREES OFF DUE SOUTH *******

INCLINATION=	*	0	15	30	45	60	75	90	DEGREES
JAN	*	1406	2143	2766	3230	3504	3569	3422	
FEB	*	2453	3295	3962	4409	4604	4534	4205	
MAR	*	4008	4789	5326	5580	5532	5187	4568	
APR	*	4917	5284	5420	5308	4953	4378	3627	
MAY	*	5917	6024	5906	5551	4977	4222	3347	
JUN	*	6381	6357	6120	5657	4989	4162	3244	
JUL	*	6833	6885	6689	6227	5521	4620	3598	
AUG	*	5633	5924	5967	5744	5266	4567	3699	
SEP	*	4006	4523	4827	4895	4720	4314	3707	
OCT	*	2625	3313	3833	4148	4236	4093	3726	
NOV	*	1453	2068	2577	2943	3141	3159	2996	
DEC	*	1081	1691	2211	2605	2846	2919	2817	

******* ORIENTATION=30 DEGREES OFF DUE SOUTH *******

INCLINATION=	*	0	15	30	45	60	75	90	DEGREES
JAN	*	1406	2063	2611	3012	3237	3272	3114	
FEB	*	2453	3204	3790	4168	4313	4214	3880	
MAR	*	4008	4713	5198	5421	5363	5029	4443	
APR	*	4917	5254	5391	5298	4978	4449	3754	
MAY	*	5917	6019	5924	5608	5084	4385	3568	
JUN	*	6381	6362	6152	5730	5111	4337	3469	
JUL	*	6833	6886	6719	6306	5661	4825	3868	
AUG	*	5633	5905	5961	5773	5346	4707	3907	
SEP	*	4006	4475	4754	4815	4649	4267	3697	
OCT	*	2625	3241	3698	3965	4020	3861	3499	
NOV	*	1453	2001	2447	2759	2917	2909	2736	
DEC	*	1081	1625	2084	2425	2627	2673	2563	

******* ORIENTATION=45 DEGREES OFF DUE SOUTH *******

INCLINATION=	*	0	15	30	45	60	75	90	DEGREES
JAN	*	1406	1940	2376	2683	2838	2832	2664	
FEB	*	2453	3068	3544	3840	3932	3813	3493	
MAR	*	4008	4592	4997	5174	5103	4787	4250	
APR	*	4917	5199	5316	5233	4943	4462	3828	
MAY	*	5917	6005	5929	5659	5196	4566	3818	
JUN	*	6381	6367	6193	5830	5282	4582	3784	
JUL	*	6833	6882	6751	6402	5838	5091	4219	
AUG	*	5633	5862	5916	5755	5377	4802	4074	
SEP	*	4006	4395	4629	4671	4510	4156	3634	
OCT	*	2625	3131	3504	3711	3732	3565	3224	
NOV	*	1453	1899	2254	2492	2596	2559	2382	
DEC	*	1081	1522	1886	2147	2287	2296	2174	

TABLE A-21 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= SWIFT CURRENT - SASK. LATITUDE=50.27 DEG. N

		******* ORIENTATION=60 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1406	1788	2099	2309	2399	2362	2201
FEB	*	2453	2897	3243	3447	3487	3356	3063
MAR	*	4008	4431	4728	4843	4753	4457	3975
APR	*	4917	5118	5194	5104	4835	4397	3820
MAY	*	5917	5973	5898	5657	5243	4674	3989
JUN	*	6381	6361	6208	5891	5406	4774	4040
JUL	*	6833	6860	6744	6442	5946	5277	4481
AUG	*	5633	5795	5822	5671	5330	4810	4149
SEP	*	4006	4286	4452	4462	4300	3971	3498
OCT	*	2625	2990	3260	3398	3383	3215	2903
NOV	*	1453	1772	2026	2187	2240	2181	2014
DEC	*	1081	1395	1652	1828	1909	1889	1768

		******* ORIENTATION=75 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1406	1617	1799	1915	1948	1891	1746
FEB	*	2453	2699	2901	3009	2997	2859	2601
MAR	*	4008	4238	4401	4439	4322	4042	3615
APR	*	4917	5013	5023	4907	4645	4241	3717
MAY	*	5917	5924	5824	5589	5207	4685	4055
JUN	*	6381	6341	6184	5890	5448	4871	4191
JUL	*	6833	6820	6687	6403	5954	5347	4617
AUG	*	5633	5704	5677	5512	5190	4715	4114
SEP	*	4006	4152	4228	4191	4018	3711	3285
OCT	*	2625	2825	2977	3039	2988	2819	2542
NOV	*	1453	1629	1775	1860	1868	1795	1644
DEC	*	1081	1254	1403	1499	1529	1488	1378

		******* ORIENTATION=90 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1406	1438	1493	1525	1511	1442	1320
FEB	*	2453	2483	2533	2545	2487	2346	2126
MAR	*	4008	4021	4028	3975	3823	3557	3185
APR	*	4917	4890	4807	4642	4373	3994	3519
MAY	*	5917	5859	5705	5448	5076	4589	4007
JUN	*	6381	6308	6116	5814	5392	4853	4221
JUL	*	6833	6762	6576	6276	5845	5283	4610
AUG	*	5633	5594	5481	5274	4953	4510	3963
SEP	*	4006	3999	3964	3864	3672	3381	3000
OCT	*	2625	2644	2668	2650	2563	2396	2155
NOV	*	1453	1477	1516	1530	1501	1420	1290
DEC	*	1081	1107	1152	1178	1168	1116	1022

TABLE A-22 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= WINNIPEG - MAN. LATITUDE=49.90 DEG. N

******* ORIENTATION= 0 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN	*	1458	2246	2911	3410	3706	3781	3630
FEB	*	2544	3448	4167	4653	4872	4809	4468
MAR	*	3911	4666	5181	5420	5367	5026	4419
APR	*	4842	5198	5318	5188	4816	4228	3465
MAY	*	5767	5862	5732	5369	4791	4040	3174
JUN	*	6375	6346	6095	5613	4925	4077	3142
JUL	*	6358	6394	6193	5745	5073	4224	3268
AUG	*	5342	5602	5620	5386	4911	4231	3394
SEP	*	3728	4183	4439	4477	4295	3905	3333
OCT	*	2275	2808	3204	3436	3488	3357	3051
NOV	*	1269	1743	2130	2404	2546	2547	2406
DEC	*	1067	1655	2156	2536	2768	2836	2736

******* ORIENTATION=15 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN	*	1458	2218	2857	3333	3613	3677	3522
FEB	*	2544	3415	4104	4563	4761	4686	4341
MAR	*	3911	4640	5135	5361	5300	4958	4358
APR	*	4842	5191	5314	5196	4841	4275	3538
MAY	*	5767	5861	5739	5388	4828	4096	3250
JUN	*	6375	6348	6107	5640	4969	4140	3223
JUL	*	6358	6395	6203	5770	5117	4289	3354
AUG	*	5342	5597	5621	5400	4944	4285	3473
SEP	*	3728	4170	4422	4461	4285	3906	3351
OCT	*	2275	2788	3166	3382	3422	3282	2974
NOV	*	1269	1726	2097	2357	2489	2483	2340
DEC	*	1067	1634	2116	2479	2698	2758	2655

******* ORIENTATION=30 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN	*	1458	2136	2699	3109	3338	3370	3204
FEB	*	2544	3321	3925	4314	4461	4356	4006
MAR	*	3911	4569	5016	5212	5143	4812	4243
APR	*	4842	5163	5286	5187	4866	4344	3663
MAY	*	5767	5857	5756	5443	4930	4251	3461
JUN	*	6375	6353	6140	5714	5093	4318	3451
JUL	*	6358	6396	6231	5842	5242	4472	3594
AUG	*	5342	5580	5616	5427	5017	4413	3663
SEP	*	3728	4129	4359	4393	4225	3866	3345
OCT	*	2275	2733	3065	3245	3260	3109	2804
NOV	*	1269	1676	2000	2221	2322	2296	2147
DEC	*	1067	1573	1998	2312	2493	2529	2418

******* ORIENTATION=45 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN	*	1458	2008	2457	2771	2929	2919	2744
FEB	*	2544	3181	3672	3976	4069	3943	3609
MAR	*	3911	4455	4827	4981	4900	4587	4065
APR	*	4842	5110	5215	5125	4834	4359	3736
MAY	*	5767	5844	5762	5492	5037	4423	3699
JUN	*	6375	6359	6182	5815	5265	4565	3767
JUL	*	6358	6393	6260	5927	5399	4707	3904
AUG	*	5342	5542	5576	5412	5046	4500	3815
SEP	*	3728	4060	4250	4268	4106	3772	3291
OCT	*	2275	2651	2919	3054	3044	2888	2599
NOV	*	1269	1599	1857	2022	2083	2036	1884
DEC	*	1067	1477	1813	2052	2177	2178	2057

TABLE A-23 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= WINNIPEG - MAN. LATITUDE=49.90 DEG. N

		******* ORIENTATION=60 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1458	1852	2172	2387	2478	2438	2270	
FEB	*	2544	3003	3360	3570	3609	3471	3166	
MAR	*	3911	4305	4575	4672	4573	4279	3809	
APR	*	4842	5032	5098	5002	4732	4298	3731	
MAY	*	5767	5815	5734	5491	5083	4526	3861	
JUN	*	6375	6353	6198	5878	5390	4758	4024	
JUL	*	6358	6375	6254	5963	5495	4872	4136	
AUG	*	5342	5482	5493	5337	5005	4510	3886	
SEP	*	3728	3966	4097	4088	3925	3614	3176	
OCT	*	2275	2545	2736	2819	2782	2625	2359	
NOV	*	1269	1505	1687	1794	1818	1756	1611	
DEC	*	1067	1359	1596	1756	1826	1801	1681	

		******* ORIENTATION=75 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1458	1676	1863	1982	2014	1953	1803	
FEB	*	2544	2798	3006	3116	3103	2959	2690	
MAR	*	3911	4123	4269	4294	4169	3891	3474	
APR	*	4842	4932	4935	4814	4551	4150	3634	
MAY	*	5767	5769	5665	5429	5050	4539	3925	
JUN	*	6375	6334	6175	5877	5433	4855	4175	
JUL	*	6358	6340	6206	5931	5504	4935	4256	
AUG	*	5342	5400	5363	5195	4881	4426	3857	
SEP	*	3728	3850	3904	3854	3682	3390	2993	
OCT	*	2275	2421	2523	2549	2485	2329	2089	
NOV	*	1269	1398	1500	1551	1541	1468	1336	
DEC	*	1067	1228	1364	1449	1472	1428	1319	

		******* ORIENTATION=90 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1458	1491	1547	1579	1563	1491	1364	
FEB	*	2544	2575	2625	2636	2575	2428	2200	
MAR	*	3911	3920	3919	3858	3701	3437	3071	
APR	*	4842	4814	4728	4560	4290	3914	3445	
MAY	*	5767	5709	5554	5297	4929	4450	3881	
JUN	*	6375	6302	6108	5803	5379	4839	4207	
JUL	*	6358	6290	6111	5821	5410	4880	4252	
AUG	*	5342	5302	5187	4982	4668	4243	3722	
SEP	*	3728	3718	3676	3571	3382	3105	2748	
OCT	*	2275	2284	2289	2256	2165	2011	1798	
NOV	*	1269	1284	1306	1304	1267	1189	1073	
DEC	*	1067	1090	1130	1150	1136	1081	987	

TABLE A-24 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= CHURCHILL - MAN. LATITUDE=58.75 DEG. N

******* ORIENTATION= 0 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	636	1322	1931	2423	2763	2929	2908	
FEB *	1603	2518	3294	3878	4229	4325	4158	
MAR *	3433	4514	5347	5875	6064	5899	5392	
APR *	5400	6115	6535	6620	6360	5772	4896	
MAY *	5819	6022	6016	5763	5268	4564	3701	
JUN *	6172	6204	6062	5698	5121	4366	3490	
JUL *	5761	5857	5772	5466	4948	4251	3425	
AUG *	4447	4740	4844	4738	4423	3920	3266	
SEP *	2553	2933	3178	3272	3208	2989	2632	
OCT *	1197	1551	1831	2019	2102	2073	1936	
NOV *	644	1106	1508	1824	2032	2117	2074	
DEC *	431	1006	1523	1945	2245	2401	2404	

******* ORIENTATION=15 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	636	1298	1885	2358	2683	2840	2816	
FEB *	1603	2485	3231	3789	4121	4204	4032	
MAR *	3433	4478	5282	5788	5962	5790	5286	
APR *	5400	6100	6523	6621	6380	5816	4967	
MAY *	5819	6018	6017	5775	5295	4606	3760	
JUN *	6172	6203	6067	5714	5150	4409	3546	
JUL *	5761	5855	5775	5480	4974	4290	3477	
AUG *	4447	4734	4841	4742	4439	3949	3309	
SEP *	2553	2923	3164	3258	3197	2984	2635	
OCT *	1197	1538	1806	1984	2058	2025	1886	
NOV *	644	1090	1477	1780	1977	2056	2011	
DEC *	431	986	1484	1891	2178	2327	2326	

******* ORIENTATION=30 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	636	1228	1750	2166	2449	2578	2546	
FEB *	1603	2391	3049	3532	3806	3854	3671	
MAR *	3433	4379	5113	5573	5722	5549	5068	
APR *	5400	6051	6471	6593	6395	5887	5105	
MAY *	5819	6006	6020	5809	5369	4725	3924	
JUN *	6172	6202	6083	5759	5232	4529	3704	
JUL *	5761	5849	5784	5517	5047	4401	3626	
AUG *	4447	4715	4829	4752	4479	4026	3425	
SEP *	2553	2890	3113	3199	3139	2935	2603	
OCT *	1197	1501	1737	1888	1943	1899	1758	
NOV *	644	1042	1385	1650	1818	1879	1827	
DEC *	431	927	1371	1731	1982	2108	2100	

******* ORIENTATION=45 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	636	1116	1535	1862	2077	2163	2116	
FEB *	1603	2250	2789	3176	3383	3394	3210	
MAR *	3433	4225	4852	5243	5360	5191	4747	
APR *	5400	5956	6340	6467	6303	5852	5145	
MAY *	5819	5984	6015	5847	5466	4888	4153	
JUN *	6172	6198	6103	5824	5352	4709	3939	
JUL *	5761	5839	5794	5569	5153	4565	3847	
AUG *	4447	4677	4786	4726	4485	4074	3521	
SEP *	2553	2835	3026	3095	3032	2839	2528	
OCT *	1197	1447	1641	1759	1792	1738	1601	
NOV *	644	967	1241	1447	1571	1603	1543	
DEC *	431	834	1191	1477	1671	1761	1741	

TABLE A-25 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= CHURCHILL - MAN. LATITUDE=58.75 DEG. N

		******* ORIENTATION=60 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	636	979	1278	1507	1648	1692	1636	
FEB	*	1603	2075	2478	2762	2902	2885	2711	
MAR	*	3433	4020	4509	4813	4889	4724	4327	
APR	*	5400	5816	6127	6233	6089	5690	5057	
MAY	*	5819	5940	5967	5828	5498	4982	4312	
JUN	*	6172	6187	6111	5879	5470	4894	4187	
JUL	*	5761	5815	5780	5591	5228	4701	4042	
AUG	*	4447	4616	4699	4642	4425	4051	3544	
SEP	*	2553	2760	2903	2947	2877	2693	2406	
OCT	*	1197	1379	1522	1603	1614	1553	1423	
NOV	*	644	876	1073	1217	1296	1304	1241	
DEC	*	431	717	967	1162	1289	1338	1305	

		******* ORIENTATION=75 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	636	832	1014	1152	1230	1243	1188	
FEB	*	1603	1877	2135	2316	2393	2354	2199	
MAR	*	3433	3775	4098	4299	4328	4166	3819	
APR	*	5400	5636	5835	5892	5750	5392	4832	
MAY	*	5819	5873	5864	5730	5433	4969	4360	
JUN	*	6172	6159	6074	5866	5503	4985	4336	
JUL	*	5761	5773	5718	5544	5219	4743	4139	
AUG	*	4447	4534	4568	4496	4290	3947	3484	
SEP	*	2553	2668	2751	2760	2678	2502	2239	
OCT	*	1197	1301	1387	1430	1419	1352	1232	
NOV	*	644	777	897	982	1022	1012	952	
DEC	*	431	592	740	855	924	942	907	

		******* ORIENTATION=90 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	636	682	760	822	852	844	797	
FEB	*	1603	1665	1778	1863	1885	1831	1699	
MAR	*	3433	3502	3636	3724	3702	3544	3249	
APR	*	5400	5423	5469	5449	5291	4965	4474	
MAY	*	5819	5785	5705	5547	5264	4840	4286	
JUN	*	6172	6114	5986	5773	5435	4961	4366	
JUL	*	5761	5714	5608	5421	5114	4677	4123	
AUG	*	4447	4433	4394	4288	4080	3761	3339	
SEP	*	2553	2563	2573	2541	2443	2273	2035	
OCT	*	1197	1215	1243	1248	1218	1147	1038	
NOV	*	644	674	723	758	767	744	691	
DEC	*	431	468	530	579	605	603	572	

TABLE A-26 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= OTTAWA - ONT. LATITUDE=45.45 DEG. N

******* ORIENTATION= 0 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	1603	2184	2654	2982	3145	3131	2943	
FEB *	2622	3296	3803	4108	4192	4048	3686	
MAR *	3822	4374	4712	4811	4667	4287	3699	
APR *	4633	4881	4912	4722	4323	3743	3023	
MAY *	5394	5431	5257	4872	4300	3583	2778	
JUN *	5964	5893	5610	5119	4446	3644	2781	
JUL *	5947	5928	5685	5219	4560	3754	2870	
AUG *	5047	5214	5158	4879	4394	3737	2958	
SEP *	3722	4072	4234	4197	3962	3546	2978	
OCT *	2414	2846	3145	3290	3271	3089	2757	
NOV *	1300	1623	1872	2029	2083	2031	1877	
DEC *	1214	1653	2011	2263	2393	2391	2257	

******* ORIENTATION=15 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	1603	2163	2614	2925	3074	3053	2861	
FEB *	2622	3270	3754	4040	4108	3955	3589	
MAR *	3822	4355	4678	4768	4619	4241	3660	
APR *	4633	4876	4912	4733	4351	3791	3097	
MAY *	5394	5432	5265	4893	4339	3641	2857	
JUN *	5964	5896	5624	5146	4492	3708	2863	
JUL *	5947	5930	5697	5247	4606	3820	2958	
AUG *	5047	5211	5162	4895	4428	3792	3038	
SEP *	3722	4062	4221	4185	3957	3553	3001	
OCT *	2414	2830	3113	3245	3216	3028	2693	
NOV *	1300	1611	1849	1996	2043	1987	1831	
DEC *	1214	1637	1980	2220	2340	2332	2196	

******* ORIENTATION=30 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	1603	2101	2494	2756	2868	2823	2623	
FEB *	2622	3200	3621	3856	3888	3715	3349	
MAR *	3822	4301	4589	4661	4509	4145	3596	
APR *	4633	4855	4893	4733	4382	3865	3223	
MAY *	5394	5432	5288	4953	4445	3800	3071	
JUN *	5964	5905	5661	5225	4620	3888	3092	
JUL *	5947	5935	5730	5323	4734	4006	3200	
AUG *	5047	5199	5163	4927	4502	3917	3222	
SEP *	3722	4029	4172	4134	3917	3534	3017	
OCT *	2414	2785	3031	3134	3087	2893	2565	
NOV *	1300	1576	1781	1901	1927	1857	1697	
DEC *	1214	1591	1891	2093	2184	2158	2016	

******* ORIENTATION=45 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	1603	2006	2317	2511	2574	2502	2300	
FEB *	2622	3094	3431	3605	3600	3418	3072	
MAR *	3822	4216	4449	4492	4337	3994	3489	
APR *	4633	4816	4843	4695	4373	3899	3311	
MAY *	5394	5425	5301	5006	4551	3966	3296	
JUN *	5964	5914	5706	5326	4786	4123	3390	
JUL *	5947	5937	5764	5409	4886	4229	3489	
AUG *	5047	5173	5139	4927	4543	4011	3374	
SEP *	3722	3974	4087	4040	3831	3475	2998	
OCT *	2414	2716	2911	2980	2915	2721	2412	
NOV *	1300	1523	1683	1767	1768	1686	1527	
DEC *	1214	1518	1753	1901	1952	1903	1756	

TABLE A-27 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= OTTAWA - ONT. LATITUDE=45.45 DEG. N

		******* ORIENTATION=60 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1603	1890	2106	2229	2247	2158	1968	
FEB	*	2622	2958	3195	3300	3260	3076	2759	
MAR	*	3822	4102	4260	4263	4100	3779	3321	
APR	*	4633	4758	4758	4609	4309	3874	3334	
MAY	*	5394	5407	5288	5021	4609	4075	3456	
JUN	*	5964	5916	5731	5394	4910	4307	3627	
JUL	*	5947	5929	5772	5456	4987	4390	3708	
AUG	*	5047	5130	5082	4882	4530	4044	3459	
SEP	*	3722	3898	3965	3899	3695	3362	2926	
OCT	*	2414	2628	2759	2787	2704	2513	2229	
NOV	*	1300	1458	1565	1611	1588	1499	1349	
DEC	*	1214	1429	1591	1683	1697	1631	1490	

		******* ORIENTATION=75 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1603	1757	1873	1926	1904	1804	1634	
FEB	*	2622	2801	2923	2955	2879	2695	2413	
MAR	*	3822	3965	4028	3978	3800	3497	3085	
APR	*	4633	4683	4636	4471	4180	3775	3279	
MAY	*	5394	5376	5244	4986	4602	4107	3531	
JUN	*	5964	5908	5726	5412	4967	4409	3773	
JUL	*	5947	5909	5746	5449	5016	4465	3830	
AUG	*	5047	5071	4989	4783	4449	3999	3458	
SEP	*	3722	3806	3810	3713	3505	3192	2793	
OCT	*	2414	2524	2581	2563	2460	2273	2015	
NOV	*	1300	1382	1434	1441	1397	1303	1166	
DEC	*	1214	1329	1414	1451	1433	1357	1228	

		******* ORIENTATION=90 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1603	1616	1630	1618	1562	1458	1310	
FEB	*	2622	2630	2628	2583	2473	2292	2046	
MAR	*	3822	3810	3761	3645	3444	3155	2787	
APR	*	4633	4594	4479	4279	3984	3600	3142	
MAY	*	5394	5334	5165	4893	4518	4050	3511	
JUN	*	5964	5890	5687	5369	4940	4414	3814	
JUL	*	5947	5877	5683	5377	4958	4439	3844	
AUG	*	5047	4999	4860	4627	4294	3868	3367	
SEP	*	3722	3699	3625	3484	3263	2964	2600	
OCT	*	2414	2410	2385	2316	2191	2010	1778	
NOV	*	1300	1302	1296	1266	1204	1108	984	
DEC	*	1214	1223	1232	1220	1175	1094	981	

TABLE A-28 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= TORONTO - ONT. LATITUDE=43.40 DEG. N

		******* ORIENTATION= 0 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1683	2214	2634	2917	3041	3000	2795
FEB	*	2536	3084	3482	3702	3729	3562	3212
MAR	*	3583	4011	4251	4285	4111	3742	3202
APR	*	4906	5149	5161	4938	4496	3865	3090
MAY	*	5375	5389	5193	4790	4207	3486	2687
JUN	*	5817	5728	5432	4934	4266	3477	2640
JUL	*	6181	6138	5860	5352	4645	3792	2869
AUG	*	5289	5444	5364	5049	4520	3814	2985
SEP	*	3903	4245	4390	4328	4064	3614	3011
OCT	*	2528	2935	3206	3323	3277	3072	2721
NOV	*	1289	1559	1759	1876	1902	1835	1680
DEC	*	1183	1528	1801	1983	2063	2034	1899

		******* ORIENTATION=15 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1683	2194	2597	2864	2977	2928	2720
FEB	*	2536	3063	3442	3646	3660	3485	3133
MAR	*	3583	3996	4225	4252	4075	3707	3174
APR	*	4906	5144	5161	4952	4528	3921	3177
MAY	*	5375	5390	5202	4814	4248	3547	2769
JUN	*	5817	5732	5446	4963	4312	3543	2723
JUL	*	6181	6141	5874	5383	4697	3867	2967
AUG	*	5289	5441	5369	5068	4559	3878	3078
SEP	*	3903	4235	4377	4318	4061	3625	3040
OCT	*	2528	2919	3176	3280	3225	3013	2661
NOV	*	1289	1548	1740	1849	1869	1798	1641
DEC	*	1183	1515	1776	1949	2021	1987	1851

		******* ORIENTATION=30 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1683	2138	2488	2709	2787	2716	2501
FEB	*	2536	3005	3333	3495	3481	3292	2941
MAR	*	3583	3954	4155	4168	3992	3638	3133
APR	*	4906	5123	5145	4957	4569	4009	3323
MAY	*	5375	5392	5227	4877	4359	3712	2990
JUN	*	5817	5742	5485	5045	4444	3727	2956
JUL	*	6181	6149	5913	5470	4842	4076	3239
AUG	*	5289	5431	5374	5107	4645	4020	3286
SEP	*	3903	4202	4329	4270	4025	3614	3067
OCT	*	2528	2876	3098	3177	3105	2889	2544
NOV	*	1289	1519	1683	1769	1771	1689	1529
DEC	*	1183	1478	1705	1848	1897	1850	1708

		******* ORIENTATION=45 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1683	2051	2326	2486	2521	2428	2214
FEB	*	2536	2918	3177	3291	3249	3055	2723
MAR	*	3583	3886	4044	4037	3860	3526	3061
APR	*	4906	5084	5096	4923	4569	4058	3431
MAY	*	5375	5388	5245	4934	4469	3881	3218
JUN	*	5817	5754	5533	5147	4611	3961	3251
JUL	*	6181	6154	5954	5567	5010	4319	3552
AUG	*	5289	5406	5353	5115	4698	4132	3462
SEP	*	3903	4148	4246	4179	3946	3563	3061
OCT	*	2528	2811	2985	3031	2944	2731	2407
NOV	*	1289	1475	1601	1657	1639	1548	1390
DEC	*	1183	1421	1597	1698	1716	1651	1507

TABLE A-29 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= TORONTO - ONT. LATITUDE=43.40 DEG. N

		******* ORIENTATION=60 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1683	1944	2132	2229	2224	2118	1917	
FEB	*	2536	2807	2983	3042	2972	2779	2474	
MAR	*	3583	3796	3895	3857	3676	3362	2937	
APR	*	4906	5026	5012	4841	4512	4044	3470	
MAY	*	5375	5373	5238	4957	4535	3997	3383	
JUN	*	5817	5759	5563	5220	4738	4145	3484	
JUL	*	6181	6149	5969	5626	5127	4500	3791	
AUG	*	5289	5364	5300	5077	4697	4180	3565	
SEP	*	3903	4073	4127	4042	3816	3460	3001	
OCT	*	2528	2727	2841	2849	2746	2538	2240	
NOV	*	1289	1419	1501	1526	1489	1393	1244	
DEC	*	1183	1351	1469	1526	1516	1440	1303	

		******* ORIENTATION=75 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1683	1821	1918	1951	1911	1797	1616	
FEB	*	2536	2677	2759	2757	2660	2469	2195	
MAR	*	3583	3687	3711	3632	3440	3143	2757	
APR	*	4906	4951	4890	4704	4387	3952	3425	
MAY	*	5375	5348	5203	4932	4539	4039	3465	
JUN	*	5817	5755	5566	5246	4801	4252	3631	
JUL	*	6181	6133	5952	5629	5169	4591	3929	
AUG	*	5289	5306	5210	4983	4623	4145	3577	
SEP	*	3903	3981	3973	3858	3630	3296	2876	
OCT	*	2528	2628	2671	2635	2515	2313	2041	
NOV	*	1289	1355	1390	1383	1328	1230	1092	
DEC	*	1183	1271	1329	1343	1309	1226	1100	

		******* ORIENTATION=90 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1683	1690	1693	1665	1595	1479	1321	
FEB	*	2536	2535	2514	2449	2324	2137	1895	
MAR	*	3583	3564	3498	3366	3157	2872	2523	
APR	*	4906	4861	4732	4509	4189	3777	3291	
MAY	*	5375	5312	5136	4853	4469	3995	3454	
JUN	*	5817	5742	5537	5216	4787	4266	3679	
JUL	*	6181	6105	5897	5567	5122	4576	3954	
AUG	*	5289	5235	5082	4828	4471	4019	3492	
SEP	*	3903	3875	3789	3630	3390	3071	2687	
OCT	*	2528	2519	2482	2399	2258	2062	1817	
NOV	*	1289	1287	1272	1233	1164	1065	940	
DEC	*	1183	1186	1183	1158	1103	1018	905	

TABLE A-30 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= MONTREAL - QUE. LATITUDE=45.50 DEG. N

******* ORIENTATION= 0 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	1464	1958	2356	2630	2761	2741	2570	
FEB *	2425	3009	3444	3701	3762	3623	3294	
MAR *	3472	3933	4207	4275	4132	3788	3267	
APR *	4392	4613	4633	4448	4071	3527	2856	
MAY *	5150	5180	5012	4647	4107	3432	2676	
JUN *	5750	5682	5411	4941	4299	3532	2708	
JUL *	5886	5867	5627	5168	4518	3724	2854	
AUG *	4772	4919	4861	4595	4140	3527	2802	
SEP *	3672	4012	4167	4127	3895	3486	2928	
OCT *	2294	2690	2961	3089	3065	2891	2579	
NOV *	1242	1537	1763	1903	1949	1897	1750	
DEC *	1050	1393	1670	1862	1955	1944	1829	

******* ORIENTATION=15 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	1464	1940	2322	2581	2701	2674	2501	
FEB *	2425	2987	3402	3642	3689	3542	3210	
MAR *	3472	3917	4179	4238	4092	3749	3235	
APR *	4392	4608	4632	4458	4096	3571	2923	
MAY *	5150	5181	5020	4667	4143	3485	2747	
JUN *	5750	5685	5424	4967	4341	3592	2784	
JUL *	5886	5868	5638	5194	4562	3789	2939	
AUG *	4772	4917	4864	4610	4171	3576	2874	
SEP *	3672	4002	4154	4116	3890	3492	2951	
OCT *	2294	2675	2932	3048	3015	2835	2520	
NOV *	1242	1526	1741	1873	1912	1856	1708	
DEC *	1050	1380	1646	1828	1914	1898	1781	

******* ORIENTATION=30 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	1464	1888	2220	2438	2525	2478	2298	
FEB *	2425	2925	3286	3481	3497	3333	3000	
MAR *	3472	3872	4104	4148	3999	3669	3180	
APR *	4392	4589	4616	4458	4124	3637	3036	
MAY *	5150	5181	5040	4721	4239	3629	2941	
JUN *	5750	5693	5458	5040	4460	3760	2998	
JUL *	5886	5874	5670	5268	4688	3970	3175	
AUG *	4772	4906	4865	4638	4237	3689	3039	
SEP *	3672	3969	4106	4066	3851	3474	2966	
OCT *	2294	2634	2857	2947	2897	2711	2402	
NOV *	1242	1494	1680	1786	1806	1737	1585	
DEC *	1050	1344	1575	1728	1792	1762	1640	

******* ORIENTATION=45 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	1464	1807	2068	2228	2274	2203	2022	
FEB *	2425	2833	3121	3263	3247	3075	2759	
MAR *	3472	3800	3986	4006	3855	3541	3090	
APR *	4392	4554	4570	4423	4116	3668	3115	
MAY *	5150	5175	5052	4769	4335	3779	3145	
JUN *	5750	5702	5500	5134	4616	3979	3276	
JUL *	5886	5876	5703	5352	4836	4186	3456	
AUG *	4772	4882	4843	4639	4274	3774	3176	
SEP *	3672	3916	4023	3974	3767	3416	2947	
OCT *	2294	2571	2747	2805	2739	2553	2262	
NOV *	1242	1446	1590	1663	1660	1580	1430	
DEC *	1050	1287	1468	1578	1610	1561	1436	

TABLE A-31 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= MONTREAL - QUE. LATITUDE=45.50 DEG. N

		******* ORIENTATION=60 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1464	1707	1888	1987	1995	1909	1738	
FEB	*	2425	2715	2915	2998	2951	2777	2487	
MAR	*	3472	3704	3827	3813	3655	3360	2949	
APR	*	4392	4502	4493	4346	4058	3645	3136	
MAY	*	5150	5158	5040	4782	4388	3878	3290	
JUN	*	5750	5703	5524	5197	4731	4150	3496	
JUL	*	5886	5868	5711	5398	4934	4343	3669	
AUG	*	4772	4843	4792	4598	4262	3803	3252	
SEP	*	3672	3843	3906	3838	3635	3307	2877	
OCT	*	2294	2490	2607	2628	2545	2363	2094	
NOV	*	1242	1385	1482	1520	1[illegible]6	1409	1266	
DEC	*	1050	1217	1340	1406	1409	1348	1227	

		******* ORIENTATION=75 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1464	1594	1689	1728	1702	1608	1452	
FEB	*	2425	2579	2679	2698	2620	2446	2186	
MAR	*	3472	3589	3632	3574	3403	3123	2750	
APR	*	4392	4434	4383	4221	3941	3555	3086	
MAY	*	5150	5130	5000	4750	4381	3907	3358	
JUN	*	5750	5695	5519	5214	4783	4245	3632	
JUL	*	5886	5847	5686	5390	4962	4416	3788	
AUG	*	4772	4790	4708	4509	4189	3761	3252	
SEP	*	3672	3752	3755	3657	3450	3141	2747	
OCT	*	2294	2395	2444	2422	2321	2142	1897	
NOV	*	1242	1316	1362	1365	1321	1230	1098	
DEC	*	1050	1139	1202	1225	1202	1133	1022	

		******* ORIENTATION=90 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1464	1473	1482	1466	1410	1312	1176	
FEB	*	2425	2430	2423	2374	2267	2096	1866	
MAR	*	3472	3459	3407	3293	3103	2835	2499	
APR	*	4392	4354	4242	4047	3764	3397	2963	
MAY	*	5150	5091	4928	4665	4305	3855	3340	
JUN	*	5750	5678	5482	5173	4759	4249	3671	
JUL	*	5886	5816	5624	5320	4905	4391	3801	
AUG	*	4772	4725	4592	4367	4049	3644	3169	
SEP	*	3672	3649	3575	3434	3215	2920	2560	
OCT	*	2294	2290	2263	2195	2075	1900	1679	
NOV	*	1242	1243	1235	1204	1143	1051	932	
DEC	*	1050	1056	1059	1043	1000	927	828	

TABLE A-32 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= MONCTON - N.B. LATITUDE=46.07 DEG. N

		******* ORIENTATION= 0 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1164	1508	1781	1965	2047	2020	1888
FEB	*	2094	2558	2899	3096	3134	3010	2734
MAR	*	3372	3822	4091	4161	4026	3697	3194
APR	*	4419	4654	4684	4506	4131	3585	2907
MAY	*	5117	5152	4991	4633	4101	3432	2682
JUN	*	5233	5175	4936	4519	3948	3265	2529
JUL	*	5467	5450	5233	4817	4227	3506	2713
AUG	*	4769	4923	4871	4611	4160	3550	2827
SEP	*	3606	3947	4107	4075	3852	3454	2907
OCT	*	2442	2899	3220	3381	3373	3194	2859
NOV	*	1278	1605	1859	2022	2081	2035	1884
DEC	*	1047	1408	1702	1908	2012	2008	1895

		******* ORIENTATION=15 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1164	1495	1757	1931	2005	1974	1840
FEB	*	2094	2540	2866	3048	3076	2945	2666
MAR	*	3372	3806	4064	4125	3987	3658	3162
APR	*	4419	4649	4684	4516	4156	3629	2974
MAY	*	5117	5152	4998	4652	4135	3484	2751
JUN	*	5233	5177	4946	4540	3983	3315	2593
JUL	*	5467	5452	5243	4840	4265	3561	2786
AUG	*	4769	4920	4873	4625	4190	3599	2897
SEP	*	3606	3937	4094	4064	3847	3459	2929
OCT	*	2442	2882	3186	3334	3315	3130	2792
NOV	*	1278	1593	1836	1989	2041	1990	1838
DEC	*	1047	1395	1677	1873	1969	1959	1844

		******* ORIENTATION=30 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1164	1459	1686	1830	1882	1836	1698
FEB	*	2094	2491	2773	2920	2922	2778	2498
MAR	*	3372	3762	3991	4037	3896	3578	3107
APR	*	4419	4629	4666	4515	4184	3695	3088
MAY	*	5117	5152	5017	4705	4229	3625	2941
JUN	*	5233	5184	4975	4601	4083	3455	2771
JUL	*	5467	5455	5270	4903	4372	3716	2988
AUG	*	4769	4909	4874	4653	4255	3710	3060
SEP	*	3606	3905	4046	4013	3806	3439	2940
OCT	*	2442	2834	3099	3217	3178	2986	2654
NOV	*	1278	1558	1768	1892	1923	1858	1702
DEC	*	1047	1357	1603	1768	1841	1816	1696

		******* ORIENTATION=45 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1164	1402	1580	1683	1705	1643	1503
FEB	*	2094	2418	2641	2746	2721	2571	2304
MAR	*	3372	3692	3875	3898	3753	3452	3016
APR	*	4419	4592	4618	4477	4173	3724	3166
MAY	*	5117	5145	5028	4751	4323	3773	3142
JUN	*	5233	5191	5010	4680	4213	3640	3006
JUL	*	5467	5457	5297	4974	4499	3902	3231
AUG	*	4769	4884	4851	4651	4290	3792	3195
SEP	*	3606	3851	3963	3920	3721	3379	2918
OCT	*	2442	2762	2973	3053	2996	2803	2491
NOV	*	1278	1505	1668	1756	1761	1683	1528
DEC	*	1047	1297	1489	1609	1649	1604	1480

TABLE A-33 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= MONCTON - N.B. LATITUDE=46.07 DEG. N

		******* ORIENTATION=60 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1164	1332	1453	1514	1509	1436	1302	
FEB	*	2094	2324	2478	2534	2485	2331	2085	
MAR	*	3372	3599	3720	3709	3558	3273	2875	
APR	*	4419	4537	4537	4395	4110	3697	3184	
MAY	*	5117	5128	5015	4762	4373	3869	3284	
JUN	*	5233	5191	5028	4732	4309	3784	3192	
JUL	*	5467	5449	5303	5012	4583	4037	3414	
AUG	*	4769	4845	4798	4608	4276	3818	3268	
SEP	*	3606	3778	3845	3783	3587	3267	2845	
OCT	*	2442	2669	2813	2850	2772	2583	2295	
NOV	*	1278	1438	1549	1598	1579	1493	1346	
DEC	*	1047	1224	1356	1429	1437	1379	1259	

		******* ORIENTATION=75 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1164	1253	1314	1333	1303	1225	1102	
FEB	*	2094	2215	2290	2295	2220	2067	1843	
MAR	*	3372	3486	3530	3476	3311	3040	2679	
APR	*	4419	4466	4421	4264	3988	3602	3129	
MAY	*	5117	5099	4973	4728	4364	3895	3349	
JUN	*	5233	5184	5022	4744	4352	3862	3306	
JUL	*	5467	5430	5279	5003	4604	4098	3516	
AUG	*	4769	4790	4711	4516	4200	3774	3265	
SEP	*	3606	3687	3694	3601	3402	3100	2714	
OCT	*	2442	2560	2625	2614	2514	2329	2068	
NOV	*	1278	1362	1416	1426	1385	1294	1159	
DEC	*	1047	1141	1210	1238	1219	1152	1042	

		******* ORIENTATION=90 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1164	1169	1170	1150	1100	1018	908	
FEB	*	2094	2096	2086	2038	1939	1787	1588	
MAR	*	3372	3360	3311	3203	3020	2760	2434	
APR	*	4419	4383	4273	4083	3802	3436	2999	
MAY	*	5117	5059	4899	4641	4285	3841	3329	
JUN	*	5233	5168	4989	4707	4328	3864	3337	
JUL	*	5467	5402	5223	4939	4552	4073	3525	
AUG	*	4769	4724	4592	4371	4056	3653	3179	
SEP	*	3606	3584	3514	3379	3167	2878	2526	
OCT	*	2442	2440	2418	2354	2232	2050	1817	
NOV	*	1278	1281	1277	1249	1190	1097	975	
DEC	*	1047	1054	1061	1048	1007	936	838	

TABLE A-34 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= FREDERICTON - N.B. LATITUDE=45.92 DEG. N

		******* ORIENTATION= 0 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1519	2074	2524	2839	2997	2987	2811
FEB	*	2464	3078	3540	3817	3890	3755	3421
MAR	*	3500	3981	4272	4351	4215	3871	3344
APR	*	4347	4571	4596	4418	4048	3511	2848
MAY	*	4978	5008	4848	4499	3984	3339	2616
JUN	*	5711	5647	5383	4919	4285	3525	2706
JUL	*	5439	5421	5204	4789	4200	3482	2693
AUG	*	4828	4985	4933	4669	4211	3590	2854
SEP	*	3636	3978	4138	4103	3877	3474	2923
OCT	*	2400	2838	3144	3295	3281	3104	2775
NOV	*	1358	1720	2001	2183	2252	2205	2044
DEC	*	1136	1550	1888	2127	2251	2251	2127

		******* ORIENTATION=15 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1519	2054	2485	2784	2930	2912	2733
FEB	*	2464	3056	3496	3755	3814	3670	3332
MAR	*	3500	3964	4242	4313	4173	3830	3310
APR	*	4347	4566	4595	4427	4072	3554	2913
MAY	*	4978	5008	4855	4518	4017	3388	2682
JUN	*	5711	5650	5394	4945	4326	3584	2781
JUL	*	5439	5423	5214	4811	4239	3537	2766
AUG	*	4828	4982	4936	4684	4242	3640	2927
SEP	*	3636	3968	4125	4092	3872	3481	2945
OCT	*	2400	2822	3111	3249	3225	3041	2710
NOV	*	1358	1706	1975	2146	2208	2155	1993
DEC	*	1136	1535	1859	2086	2201	2195	2069

		******* ORIENTATION=30 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1519	1995	2372	2624	2733	2693	2506
FEB	*	2464	2991	3374	3586	3612	3449	3111
MAR	*	3500	3917	4164	4219	4076	3745	3252
APR	*	4347	4548	4578	4426	4099	3619	3024
MAY	*	4978	5008	4873	4567	4106	3521	2861
JUN	*	5711	5657	5428	5016	4443	3748	2991
JUL	*	5439	5427	5241	4874	4345	3692	2968
AUG	*	4828	4971	4937	4713	4309	3755	3095
SEP	*	3636	3936	4077	4042	3832	3461	2958
OCT	*	2400	2776	3028	3137	3094	2904	2579
NOV	*	1358	1668	1900	2040	2078	2011	1843
DEC	*	1136	1491	1774	1967	2054	2032	1900

		******* ORIENTATION=45 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1519	1905	2202	2388	2451	2385	2195
FEB	*	2464	2894	3200	3356	3348	3177	2856
MAR	*	3500	3842	4041	4071	3924	3611	3156
APR	*	4347	4512	4532	4390	4089	3647	3100
MAY	*	4978	5001	4883	4611	4194	3660	3050
JUN	*	5711	5666	5469	5108	4596	3965	3265
JUL	*	5439	5428	5268	4946	4472	3878	3210
AUG	*	4828	4946	4913	4711	4346	3840	3234
SEP	*	3636	3882	3993	3949	3747	3401	2937
OCT	*	2400	2707	2907	2980	2919	2729	2422
NOV	*	1358	1609	1791	1890	1900	1818	1652
DEC	*	1136	1423	1645	1785	1835	1790	1654

TABLE A-35 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= FREDERICTON - N.B. LATITUDE=45.92 DEG. N

******* ORIENTATION=60 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	1519	1793	2000	2119	2138	2055	1876	
FEB *	2464	2770	2984	3077	3036	2862	2568	
MAR *	3500	3743	3876	3870	3716	3421	3006	
APR *	4347	4459	4454	4312	4029	3622	3118	
MAY *	4978	4985	4871	4622	4242	3751	3184	
JUN *	5711	5667	5491	5170	4709	4133	3483	
JUL *	5439	5420	5274	4984	4556	4013	3393	
AUG *	4828	4905	4859	4668	4332	3868	3310	
SEP *	3636	3808	3875	3811	3613	3289	2864	
OCT *	2400	2617	2753	2785	2705	2517	2235	
NOV *	1358	1535	1660	1716	1699	1609	1452	
DEC *	1136	1339	1492	1579	1593	1533	1402	

******* ORIENTATION=75 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	1519	1667	1778	1830	1810	1717	1555	
FEB *	2464	2627	2737	2762	2688	2514	2250	
MAR *	3500	3623	3673	3621	3453	3173	2798	
APR *	4347	4391	4344	4186	3911	3531	3066	
MAY *	4978	4958	4832	4590	4233	3776	3246	
JUN *	5711	5658	5485	5185	4759	4226	3617	
JUL *	5439	5402	5251	4976	4578	4074	3494	
AUG *	4828	4850	4771	4574	4254	3823	3307	
SEP *	3636	3718	3723	3629	3427	3122	2733	
OCT *	2400	2513	2573	2558	2458	2274	2017	
NOV *	1358	1452	1513	1527	1486	1391	1247	
DEC *	1136	1245	1325	1361	1345	1274	1154	

******* ORIENTATION=90 DEGREES OFF DUE SOUTH *******

INCLINATION=	0	15	30	45	60	75	90	DEGREES
JAN *	1519	1532	1548	1537	1484	1387	1246	
FEB *	2464	2470	2468	2423	2318	2146	1914	
MAR *	3500	3488	3440	3330	3142	2874	2537	
APR *	4347	4310	4201	4011	3733	3371	2941	
MAY *	4978	4921	4763	4509	4160	3726	3227	
JUN *	5711	5640	5447	5142	4732	4228	3654	
JUL *	5439	5374	5196	4912	4527	4050	3504	
AUG *	4828	4781	4649	4426	4107	3699	3220	
SEP *	3636	3614	3543	3406	3191	2900	2544	
OCT *	2400	2397	2374	2308	2186	2007	1777	
NOV *	1358	1362	1380	1332	1270	1173	1044	
DEC *	1136	1145	1155	1144	1102	1027	921	

TABLE A-36 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= HALIFAX - N.S. LATITUDE=44.65 DEG. N

		******* ORIENTATION= 0 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1428	1863	2209	2440	2543	2509	2341
FEB	*	2208	2667	3000	3183	3205	3063	2768
MAR	*	3397	3817	4058	4103	3949	3607	3101
APR	*	4072	4254	4255	4072	3717	3215	2602
MAY	*	4722	4737	4573	4234	3742	3130	2450
JUN	*	5592	5518	5247	4784	4156	3410	2612
JUL	*	5275	5245	5022	4611	4037	3341	2583
AUG	*	4922	5068	5000	4718	4241	3601	2848
SEP	*	3839	4194	4355	4310	4061	3626	3035
OCT	*	2528	2974	3280	3425	3399	3204	2853
NOV	*	1461	1834	2121	2303	2367	2309	2132
DEC	*	1022	1319	1556	1715	1786	1764	1650

		******* ORIENTATION=15 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1428	1847	2178	2397	2490	2450	2280
FEB	*	2208	2650	2966	3136	3147	2999	2701
MAR	*	3397	3802	4032	4070	3913	3572	3072
APR	*	4072	4251	4255	4081	3739	3254	2662
MAY	*	4722	4737	4580	4252	3772	3176	2513
JUN	*	5592	5521	5259	4809	4198	3469	2687
JUL	*	5275	5247	5032	4634	4074	3395	2654
AUG	*	4922	5065	5004	4734	4274	3655	2926
SEP	*	3839	4184	4341	4298	4057	3635	3061
OCT	*	2528	2957	3247	3379	3342	3141	2787
NOV	*	1461	1820	2095	2266	2321	2257	2079
DEC	*	1022	1308	1535	1685	1749	1723	1608

		******* ORIENTATION=30 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1428	1801	2088	2270	2334	2276	2100
FEB	*	2208	2601	2875	3009	2995	2834	2537
MAR	*	3397	3760	3963	3987	3829	3501	3026
APR	*	4072	4235	4241	4083	3766	3315	2764
MAY	*	4722	4738	4599	4300	3857	3303	2682
JUN	*	5592	5529	5294	4882	4315	3634	2896
JUL	*	5275	5252	5060	4696	4179	3546	2850
AUG	*	4922	5055	5006	4766	4345	3775	3103
SEP	*	3839	4150	4292	4247	4017	3619	3082
OCT	*	2528	2910	3162	3265	3211	3003	2657
NOV	*	1461	1780	2017	2156	2187	2108	1924
DEC	*	1022	1277	1473	1598	1643	1605	1486

		******* ORIENTATION=45 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1428	1729	1954	2085	2113	2036	1859
FEB	*	2208	2528	2744	2837	2798	2632	2349
MAR	*	3397	3694	3855	3858	3698	3387	2948
APR	*	4072	4205	4204	4054	3762	3345	2837
MAY	*	4722	4734	4610	4342	3941	3433	2859
JUN	*	5592	5539	5336	4974	4466	3847	3166
JUL	*	5275	5254	5088	4766	4301	3724	3081
AUG	*	4922	5031	4985	4768	4387	3867	3250
SEP	*	3839	4094	4205	4152	3932	3561	3067
OCT	*	2528	2840	3039	3106	3034	2827	2502
NOV	*	1461	1719	1905	2002	2005	1912	1731
DEC	*	1022	1227	1380	1468	1485	1431	1310

TABLE A-37 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= HALIFAX - N.S. LATITUDE=44.65 DEG. N

		******* ORIENTATION=60 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1428	1641	1795	1873	1868	1778	1611	
FEB	*	2208	2435	2581	2627	2565	2397	2136	
MAR	*	3397	3607	3709	3682	3517	3223	2822	
APR	*	4072	4160	4139	3990	3715	3329	2859	
MAY	*	4722	4720	4602	4356	3989	3521	2985	
JUN	*	5592	5541	5360	5037	4580	4013	3379	
JUL	*	5275	5249	5096	4805	4384	3854	3256	
AUG	*	4922	4992	4934	4729	4379	3903	3334	
SEP	*	3839	4017	4082	4010	3795	3450	2998	
OCT	*	2528	2748	2882	2907	2817	2615	2316	
NOV	*	1461	1643	1769	1823	1799	1698	1528	
DEC	*	1022	1167	1269	1319	1312	1247	1130	

		******* ORIENTATION=75 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1428	1541	1619	1645	1609	1512	1360	
FEB	*	2208	2326	2393	2388	2302	2136	1899	
MAR	*	3397	3500	3530	3462	3286	3007	2642	
APR	*	4072	4103	4045	3884	3617	3255	2820	
MAY	*	4722	4698	4570	4332	3986	3549	3046	
JUN	*	5592	5536	5359	5056	4633	4107	3511	
JUL	*	5275	5234	5079	4803	4410	3917	3355	
AUG	*	4922	4939	4850	4641	4308	3864	3338	
SEP	*	3839	3923	3924	3820	3602	3278	2865	
OCT	*	2528	2641	2698	2675	2565	2368	2097	
NOV	*	1461	1557	1617	1627	1579	1474	1318	
DEC	*	1022	1098	1148	1161	1132	1061	953	

		******* ORIENTATION=90 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1428	1434	1435	1411	1351	1251	1117	
FEB	*	2208	2207	2189	2131	2021	1858	1646	
MAR	*	3397	3381	3323	3204	3010	2743	2412	
APR	*	4072	4035	3925	3736	3466	3121	2716	
MAY	*	4722	4667	4512	4264	3925	3508	3033	
JUN	*	5592	5521	5327	5022	4614	4115	3551	
JUL	*	5275	5211	5032	4750	4368	3900	3369	
AUG	*	4922	4873	4732	4498	4167	3746	3256	
SEP	*	3839	3814	3735	3586	3356	3046	2670	
OCT	*	2528	2523	2493	2419	2287	2095	1852	
NOV	*	1461	1463	1457	1424	1355	1249	1109	
DEC	*	1022	1025	1023	1002	955	881	784	

TABLE A-38 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= ST.JOHN'S - NFLD. LATITUDE=47.52 DEG. N

******* ORIENTATION= 0 DEGREES OFF DUE SOUTH *******

INCLINATION=	*	0	15	30	45	60	75	90	DEGREES
JAN	*	1186	1600	1936	2171	2289	2282	2150	
FEB	*	1964	2419	2759	2961	3010	2904	2650	
MAR	*	2931	3308	3533	3591	3477	3199	2777	
APR	*	3708	3889	3908	3760	3455	3014	2469	
MAY	*	4617	4652	4514	4205	3742	3157	2498	
JUN	*	5278	5229	5001	4592	4026	3344	2602	
JUL	*	5592	5590	5384	4970	4373	3636	2819	
AUG	*	4256	4389	4346	4122	3734	3207	2580	
SEP	*	3292	3604	3754	3730	3534	3180	2692	
OCT	*	1931	2257	2482	2590	2574	2434	2180	
NOV	*	1117	1411	1642	1792	1851	1815	1688	
DEC	*	836	1117	1345	1506	1587	1585	1498	

******* ORIENTATION=15 DEGREES OFF DUE SOUTH *******

INCLINATION=	*	0	15	30	45	60	75	90	DEGREES
JAN	*	1186	1585	1907	2130	2239	2226	2093	
FEB	*	1964	2402	2726	2914	2953	2841	2584	
MAR	*	2931	3294	3510	3560	3443	3166	2748	
APR	*	3708	3885	3906	3766	3472	3045	2516	
MAY	*	4617	4651	4520	4219	3768	3198	2553	
JUN	*	5278	5231	5011	4613	4060	3392	2663	
JUL	*	5592	5592	5393	4993	4412	3692	2892	
AUG	*	4256	4387	4347	4133	3757	3245	2635	
SEP	*	3292	3595	3741	3719	3529	3184	2709	
OCT	*	1931	2244	2458	2556	2532	2387	2132	
NOV	*	1117	1401	1621	1762	1815	1775	1646	
DEC	*	836	1106	1325	1478	1554	1547	1459	

******* ORIENTATION=30 DEGREES OFF DUE SOUTH *******

INCLINATION=	*	0	15	30	45	60	75	90	DEGREES
JAN	*	1186	1541	1822	2010	2092	2062	1923	
FEB	*	1964	2354	2635	2788	2802	2675	2417	
MAR	*	2931	3257	3448	3485	3365	3095	2696	
APR	*	3708	3870	3892	3763	3490	3091	2597	
MAY	*	4617	4650	4534	4260	3842	3309	2703	
JUN	*	5278	5237	5037	4671	4155	3526	2836	
JUL	*	5592	5594	5419	5055	4519	3848	3096	
AUG	*	4256	4377	4346	4154	3807	3332	2764	
SEP	*	3292	3565	3697	3672	3489	3161	2713	
OCT	*	1931	2210	2395	2471	2433	2282	2031	
NOV	*	1117	1369	1560	1676	1709	1657	1523	
DEC	*	836	1077	1268	1397	1454	1436	1344	

******* ORIENTATION=45 DEGREES OFF DUE SOUTH *******

INCLINATION=	*	0	15	30	45	60	75	90	DEGREES
JAN	*	1186	1473	1694	1833	1878	1828	1686	
FEB	*	1964	2282	2506	2616	2603	2468	2221	
MAR	*	2931	3199	3351	3367	3242	2985	2613	
APR	*	3708	3841	3854	3732	3478	3108	2649	
MAY	*	4617	4643	4541	4296	3917	3428	2866	
JUN	*	5278	5243	5070	4747	4283	3708	3067	
JUL	*	5592	5594	5446	5128	4649	4040	3349	
AUG	*	4256	4355	4325	4149	3832	3395	2869	
SEP	*	3292	3516	3621	3586	3409	3101	2686	
OCT	*	1931	2158	2304	2353	2300	2148	1909	
NOV	*	1117	1321	1470	1552	1561	1497	1364	
DEC	*	836	1030	1179	1273	1303	1269	1173	

TABLE A-39 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= ST.JOHN'S - NFLD. LATITUDE=47.52 DEG. N

		******* ORIENTATION=60 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1186	1390	1543	1630	1642	1578	1441	
FEB	*	1964	2190	2345	2408	2370	2231	2002	
MAR	*	2931	3120	3220	3208	3076	2831	2489	
APR	*	3708	3798	3790	3666	3426	3081	2656	
MAY	*	4617	4627	4527	4301	3954	3503	2979	
JUN	*	5278	5242	5086	4796	4376	3849	3251	
JUL	*	5592	5583	5447	5163	4732	4178	3538	
AUG	*	4256	4320	4277	4109	3815	3410	2924	
SEP	*	3292	3450	3513	3460	3284	2996	2614	
OCT	*	1931	2092	2189	2206	2138	1987	1765	
NOV	*	1117	1261	1363	1409	1396	1324	1197	
DEC	*	836	973	1075	1131	1137	1091	997	

		******* ORIENTATION=75 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1186	1296	1378	1414	1396	1323	1198	
FEB	*	1964	2084	2162	2174	2110	1970	1762	
MAR	*	2931	3026	3061	3012	2868	2634	2321	
APR	*	3708	3742	3699	3562	3328	3004	2609	
MAY	*	4617	4600	4488	4268	3940	3519	3028	
JUN	*	5278	5232	5076	4803	4413	3924	3362	
JUL	*	5592	5561	5417	5147	4748	4236	3640	
AUG	*	4256	4273	4202	4027	3746	3367	2915	
SEP	*	3292	3367	3375	3294	3114	2840	2490	
OCT	*	1931	2014	2055	2037	1952	1803	1599	
NOV	*	1117	1193	1244	1255	1222	1144	1027	
DEC	*	836	909	962	983	967	914	826	

		******* ORIENTATION=90 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1186	1196	1207	1197	1154	1076	966	
FEB	*	1964	1968	1964	1924	1836	1697	1511	
MAR	*	2931	2920	2878	2784	2624	2398	2115	
APR	*	3708	3677	3584	3421	3183	2873	2507	
MAY	*	4617	4565	4422	4190	3869	3469	3007	
JUN	*	5278	5213	5037	4760	4384	3920	3390	
JUL	*	5592	5527	5352	5072	4686	4203	3645	
AUG	*	4256	4215	4099	3902	3621	3261	2839	
SEP	*	3292	3273	3212	3092	2900	2638	2317	
OCT	*	1931	1928	1907	1851	1750	1604	1418	
NOV	*	1117	1120	1119	1097	1047	967	861	
DEC	*	836	842	847	836	803	745	667	

TABLE A-40 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= CHARLOTTETOWN - P.E.I. LATITUDE=46.25 DEG. N

		******* ORIENTATION= 0 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1536	2117	2590	2924	3095	3091	2914
FEB	*	2464	3098	3577	3869	3952	3822	3487
MAR	*	3581	4088	4399	4491	4358	4009	3468
APR	*	4394	4630	4662	4487	4116	3574	2900
MAY	*	5011	5046	4889	4540	4022	3371	2640
JUN	*	5942	5878	5606	5124	4461	3665	2805
JUL	*	5686	5673	5449	5016	4399	3642	2810
AUG	*	4919	5087	5041	4776	4311	3678	2924
SEP	*	3522	3852	4006	3973	3755	3368	2837
OCT	*	2244	2644	2921	3056	3041	2875	2571
NOV	*	1383	1774	2081	2282	2365	2323	2159
DEC	*	1022	1371	1654	1853	1953	1948	1838

		******* ORIENTATION=15 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1536	2096	2550	2867	3025	3013	2833
FEB	*	2464	3074	3532	3804	3873	3734	3396
MAR	*	3581	4070	4368	4451	4314	3966	3431
APR	*	4394	4625	4661	4497	4140	3617	2966
MAY	*	5011	5046	4896	4559	4055	3420	2706
JUN	*	5942	5881	5618	5151	4505	3727	2885
JUL	*	5686	5674	5459	5040	4439	3701	2888
AUG	*	4919	5084	5044	4791	4343	3729	2998
SEP	*	3522	3842	3993	3962	3750	3373	2858
OCT	*	2244	2629	2892	3015	2990	2818	2512
NOV	*	1383	1760	2053	2243	2317	2269	2103
DEC	*	1022	1358	1630	1818	1911	1901	1789

		******* ORIENTATION=30 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1536	2034	2431	2699	2819	2784	2595
FEB	*	2464	3008	3406	3630	3664	3506	3168
MAR	*	3581	4021	4286	4351	4211	3875	3369
APR	*	4394	4605	4643	4495	4167	3682	3079
MAY	*	5011	5045	4914	4609	4145	3556	2888
JUN	*	5942	5889	5654	5227	4629	3902	3108
JUL	*	5686	5678	5488	5107	4554	3867	3104
AUG	*	4919	5073	5044	4820	4412	3847	3171
SEP	*	3522	3811	3947	3913	3710	3353	2868
OCT	*	2244	2587	2815	2912	2870	2692	2392
NOV	*	1383	1718	1972	2129	2177	2113	1942
DEC	*	1022	1321	1558	1717	1787	1763	1646

		******* ORIENTATION=45 DEGREES OFF DUE SOUTH *******						
INCLINATION=		0	15	30	45	60	75	90 DEGREES
JAN	*	1536	1940	2253	2452	2523	2460	2269
FEB	*	2464	2908	3227	3393	3392	3225	2903
MAR	*	3581	3942	4156	4195	4051	3733	3265
APR	*	4394	4568	4595	4457	4156	3710	3155
MAY	*	5011	5039	4924	4653	4235	3697	3081
JUN	*	5942	5898	5698	5325	4792	4133	3402
JUL	*	5686	5679	5517	5184	4690	4067	3365
AUG	*	4919	5046	5019	4818	4448	3934	3314
SEP	*	3522	3759	3866	3823	3628	3294	2846
OCT	*	2244	2524	2705	2769	2710	2532	2248
NOV	*	1383	1654	1854	1967	1984	1905	1735
DEC	*	1022	1264	1449	1564	1601	1558	1437

TABLE A-41 AVERAGE DAILY SOLAR RADIATION INCIDENT ON SURFACES AT VARIOUS ORIENTATIONS IN WATT-HOURS PER SQUARE METRE.

LOCATION= CHARLOTTETOWN - P.E.I. LATITUDE=46.25 DEG. N

		******* ORIENTATION=60 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1536	1823	2042	2170	2195	2114	1933	
FEB	*	2464	2781	3005	3106	3071	2900	2605	
MAR	*	3581	3838	3982	3984	3831	3532	3106	
APR	*	4394	4513	4514	4375	4093	3682	3172	
MAY	*	5011	5021	4911	4663	4283	3789	3217	
JUN	*	5942	5899	5720	5390	4912	4313	3635	
JUL	*	5686	5671	5522	5224	4779	4211	3561	
AUG	*	4919	5003	4961	4771	4432	3961	3391	
SEP	*	3522	3688	3752	3690	3498	3186	2775	
OCT	*	2244	2442	2564	2590	2514	2338	2075	
NOV	*	1383	1575	1713	1779	1768	1679	1519	
DEC	*	1022	1193	1319	1389	1397	1340	1223	

		******* ORIENTATION=75 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1536	1691	1810	1868	1852	1760	1597	
FEB	*	2464	2633	2750	2781	2712	2540	2276	
MAR	*	3581	3712	3769	3721	3554	3270	2886	
APR	*	4394	4442	4399	4243	3969	3586	3116	
MAY	*	5011	4993	4869	4629	4272	3813	3279	
JUN	*	5942	5889	5712	5404	4965	4411	3778	
JUL	*	5686	5650	5496	5213	4801	4276	3669	
AUG	*	4919	4945	4869	4672	4349	3912	3386	
SEP	*	3522	3601	3606	3515	3319	3024	2647	
OCT	*	2244	2347	2400	2383	2288	2115	1876	
NOV	*	1383	1485	1555	1575	1538	1443	1297	
DEC	*	1022	1113	1179	1205	1186	1121	1013	

		******* ORIENTATION=90 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	1536	1551	1569	1562	1512	1415	1273	
FEB	*	2464	2472	2473	2432	2330	2161	1930	
MAR	*	3581	3570	3524	3415	3227	2956	2611	
APR	*	4394	4358	4250	4062	3784	3420	2986	
MAY	*	5011	4955	4798	4545	4196	3760	3259	
JUN	*	5942	5868	5670	5357	4934	4412	3816	
JUL	*	5686	5619	5435	5143	4744	4248	3679	
AUG	*	4919	4873	4740	4516	4195	3782	3294	
SEP	*	3522	3501	3433	3300	3092	2810	2465	
OCT	*	2244	2241	2219	2156	2040	1872	1656	
NOV	*	1383	1389	1390	1365	1306	1209	1079	
DEC	*	1022	1029	1035	1022	981	912	816	

Table A-42 AVERAGE MONTHLY OUTDOOR AMBIENT TEMPERATURES IN DEGREES CELSIUS

	VANCOUVER B.C.	EDMONTON ALTA.	LETHBRIDGE ALTA.	SWIFT CURRENT SASK.	WINNIPEG MAN.	CHURCHILL MAN.	TORONTO ONT.	OTTAWA ONT.	MONTREAL QUE.	FREDERICTON N.B.	MONCTON N.B.	HALIFAX N.S.	CHARLOTTETOWN P.E.I.	ST. JOHN'S NFLD.
JAN	2	-14	-8	-13	-17	-27	-3	-10	-9	-9	-8	-3	-7	-4
FEB	3	-11	-7	-12	-15	-26	-3	-10	-7	-9	-8	-3	-7	-4
MARCH	6	-5	-2	-6	-7	-19	0	-3	-2	-3	-3	0	-3	-2
APRIL	9	4	5	4	3	-10	6	5	5	4	3	5	2	1
MAY	12	11	11	10	11	-2	12	12	12	11	9	10	9	5
JUNE	15	14	14	14	15	5	17	16	17	16	15	14	14	10
JULY	16	16	17	19	17	11	18	17	18	19	17	18	18	15
AUG	16	15	16	17	17	11	17	16	17	18	16	18	18	15
SEPT	14	10	12	11	12	5	15	14	15	14	13	16	14	11
OCT	10	5	7	6	6	-1	10	8	8	8	7	11	9	6
NOV	6	-4	0	-4	-4	-11	4	0	1	2	1	6	3	2
DEC	4	-10	-4	-11	-13	-21	-1	-8	-6	-6	-5	-1	-4	-1

TABLE A-43 TOTAL POSSIBLE NUMBER OF SUNSHINE HOURS ON SURFACES OF VARIOUS INCLINATIONS AND ORIENTATIONS FOR THE FOLLOWING LOCATIONS-

TORONTO - OTTAWA - MONTREAL - FREDERICTON - MONCTON - HALIFAX
CHARLOTTETOWN - ST.JOHN S

******* ORIENTATION= 0 DEGREES OFF DUE SOUTH *******

INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	8	8	8	8	8	8	8	
FEB	*	10	10	10	10	10	10	10	
MAR	*	11	11	11	11	11	11	11	
APR	*	13	12	12	12	11	11	10	
MAY	*	14	13	12	12	11	10	9	
JUN	*	15	13	12	12	11	10	8	
JUL	*	15	13	12	12	11	10	9	
AUG	*	13	13	12	12	11	10	10	
SEP	*	12	12	12	12	11	11	11	
OCT	*	10	10	10	10	10	10	10	
NOV	*	9	9	9	9	9	9	9	
DEC	*	8	8	8	8	8	8	8	

******* ORIENTATION=15 DEGREES OFF DUE SOUTH *******

INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	8	8	8	8	8	8	8	
FEB	*	10	10	10	10	10	10	10	
MAR	*	11	11	11	11	10	10	10	
APR	*	13	12	12	11	11	11	10	
MAY	*	14	13	12	12	11	10	9	
JUN	*	15	13	12	12	11	10	8	
JUL	*	15	13	12	12	11	10	9	
AUG	*	13	13	12	12	11	11	10	
SEP	*	12	11	11	11	11	10	10	
OCT	*	10	10	10	10	10	10	10	
NOV	*	9	9	9	9	9	9	9	
DEC	*	8	8	8	8	8	8	8	

******* ORIENTATION=30 DEGREES OFF DUE SOUTH *******

INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	8	8	8	8	8	8	8	
FEB	*	10	9	9	9	9	9	9	
MAR	*	11	11	10	10	10	9	9	
APR	*	13	12	11	11	10	10	9	
MAY	*	14	13	12	12	11	10	9	
JUN	*	15	14	13	12	11	10	9	
JUL	*	15	13	12	12	11	10	9	
AUG	*	13	12	12	11	11	10	9	
SEP	*	12	11	11	10	10	9	9	
OCT	*	10	10	10	9	9	9	9	
NOV	*	9	9	9	9	9	9	9	
DEC	*	8	8	8	8	8	8	8	

******* ORIENTATION=45 DEGREES OFF DUE SOUTH *******

INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	8	8	8	8	8	7	7	
FEB	*	10	9	9	8	8	8	7	
MAR	*	11	10	10	9	9	8	8	
APR	*	13	12	11	10	10	9	8	
MAY	*	14	13	12	11	10	9	8	
JUN	*	15	13	12	11	11	10	9	
JUL	*	15	13	12	11	10	10	9	
AUG	*	13	12	11	11	10	9	8	
SEP	*	12	11	10	10	9	9	8	
OCT	*	10	10	9	9	8	8	8	
NOV	*	9	8	8	8	8	7	7	
DEC	*	8	8	8	8	7	7	7	

TABLE A-44 TOTAL POSSIBLE NUMBER OF SUNSHINE HOURS ON SURFACES OF VARIOUS INCLINATIONS AND ORIENTATIONS FOR THE FOLLOWING LOCATIONS-

TORONTO - OTTAWA - MONTREAL - FREDERICTON - MONCTON - HALIFAX
CHARLOTTETOWN - ST.JOHN S

		******* ORIENTATION=60 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	8	8	7	7	7	6	6	
FEB	*	10	9	8	8	7	7	6	
MAR	*	11	10	9	9	8	8	7	
APR	*	13	12	11	10	9	8	7	
MAY	*	14	13	12	11	10	9	8	
JUN	*	15	13	12	11	10	9	8	
JUL	*	15	13	12	11	10	9	8	
AUG	*	13	12	11	10	9	8	8	
SEP	*	12	11	10	9	8	8	7	
OCT	*	10	9	9	8	8	7	7	
NOV	*	9	8	8	7	7	6	6	
DEC	*	8	7	7	7	6	6	6	

		******* ORIENTATION=75 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	8	7	7	6	6	5	5	
FEB	*	10	9	8	7	7	6	5	
MAR	*	11	10	9	8	7	7	6	
APR	*	13	11	10	9	8	8	7	
MAY	*	14	13	11	10	9	8	7	
JUN	*	15	13	12	11	10	9	8	
JUL	*	15	13	12	10	9	8	8	
AUG	*	13	12	11	10	9	8	7	
SEP	*	12	11	9	9	8	7	6	
OCT	*	10	9	8	7	7	6	6	
NOV	*	9	8	7	6	6	6	5	
DEC	*	8	7	6	6	6	5	5	

		******* ORIENTATION=90 DEGREES OFF DUE SOUTH *******							
INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	8	7	6	5	5	4	4	
FEB	*	10	8	7	6	6	5	5	
MAR	*	11	10	9	8	7	6	5	
APR	*	13	11	10	9	8	7	6	
MAY	*	14	13	11	10	9	8	7	
JUN	*	15	13	12	11	9	8	7	
JUL	*	15	13	12	10	9	8	7	
AUG	*	13	12	11	9	8	7	6	
SEP	*	12	10	9	8	7	6	6	
OCT	*	10	9	8	7	6	5	5	
NOV	*	9	7	6	6	5	5	4	
DEC	*	8	7	6	5	5	4	4	

TABLE A-45 TOTAL POSSIBLE NUMBER OF SUNSHINE HOURS ON SURFACES OF VARIOUS INCLINATIONS AND ORIENTATIONS FOR THE FOLLOWING LOCATIONS-

VANCOUVER - LETHBRIDGE - SWIFT CURRENT - WINNIPEG

******* ORIENTATION= 0 DEGREES OFF DUE SOUTH *******

INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	8	8	8	8	8	8	8	
FEB	*	9	9	9	9	9	9	9	
MAR	*	11	11	11	11	11	11	11	
APR	*	13	12	12	12	11	11	10	
MAY	*	15	13	12	12	11	10	9	
JUN	*	16	14	13	12	11	10	9	
JUL	*	15	14	13	12	11	10	9	
AUG	*	14	13	12	12	11	11	10	
SEP	*	12	12	12	12	11	11	11	
OCT	*	10	10	10	10	10	10	10	
NOV	*	8	8	8	8	8	8	8	
DEC	*	7	7	7	7	7	7	7	

******* ORIENTATION=15 DEGREES OFF DUE SOUTH *******

INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	8	8	8	8	8	8	8	
FEB	*	9	9	9	9	9	9	9	
MAR	*	11	11	11	11	10	10	10	
APR	*	13	12	12	12	11	11	10	
MAY	*	15	13	12	12	11	10	9	
JUN	*	16	14	13	12	11	10	9	
JUL	*	15	14	13	12	11	10	9	
AUG	*	14	13	12	12	11	11	10	
SEP	*	12	11	11	11	11	11	10	
OCT	*	10	10	10	10	10	10	10	
NOV	*	8	8	8	8	8	8	8	
DEC	*	7	7	7	7	7	7	7	

******* ORIENTATION=30 DEGREES OFF DUE SOUTH *******

INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	8	8	8	8	8	8	8	
FEB	*	9	9	9	9	9	9	9	
MAR	*	11	11	10	10	10	9	9	
APR	*	13	12	11	11	10	10	9	
MAY	*	15	13	13	12	11	11	10	
JUN	*	16	14	13	12	11	10	9	
JUL	*	15	14	13	12	11	10	9	
AUG	*	14	13	12	11	11	10	10	
SEP	*	12	11	11	10	10	10	9	
OCT	*	10	10	9	9	9	9	9	
NOV	*	8	8	8	8	8	8	8	
DEC	*	7	7	7	7	7	7	7	

******* ORIENTATION=45 DEGREES OFF DUE SOUTH *******

INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	8	8	7	7	7	7	7	
FEB	*	9	9	8	8	8	8	7	
MAR	*	11	10	10	9	9	8	8	
APR	*	13	12	11	10	10	9	8	
MAY	*	15	13	12	11	11	10	9	
JUN	*	16	14	13	12	11	10	9	
JUL	*	15	14	12	12	11	10	9	
AUG	*	14	12	11	11	10	9	9	
SEP	*	12	11	10	10	9	9	8	
OCT	*	10	9	9	9	8	8	8	
NOV	*	8	8	8	8	7	7	7	
DEC	*	7	7	7	7	7	7	7	

TABLE A-46 TOTAL POSSIBLE NUMBER OF SUNSHINE HOURS ON SURFACES OF VARIOUS INCLINATIONS AND ORIENTATIONS FOR THE FOLLOWING LOCATIONS-

VANCOUVER - LETHBRIDGE - SWIFT CURRENT - WINNIPEG

******* ORIENTATION=60 DEGREES OFF DUE SOUTH *******

INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	8	7	7	7	6	6	6	
FEB	*	9	9	8	7	7	7	6	
MAR	*	11	10	9	9	8	8	7	
APR	*	13	12	11	10	9	8	8	
MAY	*	15	13	12	11	10	9	8	
JUN	*	16	14	12	11	10	10	9	
JUL	*	15	13	12	11	10	9	8	
AUG	*	14	12	11	10	9	9	8	
SEP	*	12	11	10	9	8	8	7	
OCT	*	10	9	8	8	7	7	7	
NOV	*	8	8	7	7	7	6	6	
DEC	*	7	7	7	6	6	6	6	

******* ORIENTATION=75 DEGREES OFF DUE SOUTH *******

INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	8	7	6	6	5	5	5	
FEB	*	9	8	7	7	6	6	5	
MAR	*	11	10	9	8	7	7	6	
APR	*	13	12	10	9	8	8	7	
MAY	*	15	13	12	10	9	9	8	
JUN	*	16	14	12	11	10	9	8	
JUL	*	15	13	12	11	10	9	8	
AUG	*	14	12	11	10	9	8	7	
SEP	*	12	10	9	8	8	7	6	
OCT	*	10	9	8	7	7	6	6	
NOV	*	8	7	7	6	6	5	5	
DEC	*	7	7	6	5	5	5	5	

******* ORIENTATION=90 DEGREES OFF DUE SOUTH *******

INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	8	7	6	5	4	4	4	
FEB	*	9	8	7	6	5	5	4	
MAR	*	11	10	8	7	7	6	5	
APR	*	13	11	10	9	8	7	6	
MAY	*	15	13	11	10	9	8	7	
JUN	*	16	14	12	11	10	8	8	
JUL	*	15	13	12	10	9	8	7	
AUG	*	14	12	11	9	8	7	7	
SEP	*	12	10	9	8	7	6	6	
OCT	*	10	9	7	7	6	5	5	
NOV	*	8	7	6	5	5	4	4	
DEC	*	7	6	5	5	4	4	3	

TABLE A-47 TOTAL POSSIBLE NUMBER OF SUNSHINE HOURS ON SURFACES OF VARIOUS INCLINATIONS AND ORIENTATIONS FOR THE FOLLOWING LOCATIONS-

EDMONTON - CHURCHILL

******* ORIENTATION= 0 DEGREES OFF DUE SOUTH *******

INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	7	7	7	7	7	7	7	
FEB	*	9	9	9	9	9	9	9	
MAR	*	11	11	11	11	11	11	11	
APR	*	13	13	12	12	11	11	11	
MAY	*	16	14	13	12	11	11	10	
JUN	*	17	14	13	12	11	10	9	
JUL	*	16	14	13	12	11	10	9	
AUG	*	14	13	12	12	11	11	10	
SEP	*	12	12	12	12	11	11	11	
OCT	*	10	10	10	10	10	10	10	
NOV	*	7	7	7	7	7	7	7	
DEC	*	6	6	6	6	6	6	6	

******* ORIENTATION=15 DEGREES OFF DUE SOUTH *******

INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	7	7	7	7	7	7	7	
FEB	*	9	9	9	9	9	9	9	
MAR	*	11	11	11	11	10	10	10	
APR	*	13	13	12	12	11	11	11	
MAY	*	16	14	13	12	11	11	10	
JUN	*	17	14	13	12	11	10	9	
JUL	*	16	14	13	12	11	11	10	
AUG	*	14	13	12	12	11	11	10	
SEP	*	12	12	11	11	11	11	10	
OCT	*	10	10	10	10	10	10	10	
NOV	*	7	7	7	7	7	7	7	
DEC	*	6	6	6	6	6	6	6	

******* ORIENTATION=30 DEGREES OFF DUE SOUTH *******

INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	7	7	7	7	7	7	7	
FEB	*	9	9	9	9	8	8	8	
MAR	*	11	10	10	10	10	9	9	
APR	*	13	12	12	11	11	10	10	
MAY	*	16	14	13	12	11	11	10	
JUN	*	17	15	13	12	11	11	10	
JUL	*	16	14	13	12	11	11	10	
AUG	*	14	13	12	12	11	11	10	
SEP	*	12	11	11	10	10	10	9	
OCT	*	10	9	9	9	9	9	9	
NOV	*	7	7	7	7	7	7	7	
DEC	*	6	6	6	6	6	6	6	

******* ORIENTATION=45 DEGREES OFF DUE SOUTH *******

INCLINATION=		0	15	30	45	60	75	90	DEGREES
JAN	*	7	7	7	7	7	7	6	
FEB	*	9	8	8	8	8	7	7	
MAR	*	11	10	10	9	9	8	8	
APR	*	13	12	11	11	10	9	9	
MAY	*	16	14	13	12	11	10	10	
JUN	*	17	15	14	13	12	11	10	
JUL	*	16	14	13	12	11	11	10	
AUG	*	14	13	12	11	10	10	9	
SEP	*	12	11	10	10	9	9	8	
OCT	*	10	9	8	8	8	8	7	
NOV	*	7	7	7	7	7	7	7	
DEC	*	6	6	6	6	6	6	6	

TABLE A-48 TOTAL POSSIBLE NUMBER OF SUNSHINE HOURS ON SURFACES OF VARIOUS INCLINATIONS AND ORIENTATIONS FOR THE FOLLOWING LOCATIONS-

EDMONTON - CHURCHILL

******* ORIENTATION=60 DEGREES OFF DUE SOUTH *******

INCLINATION=	*	0	15	30	45	60	75	90	DEGREES
JAN	*	7	6	6	6	6	5	5	
FEB	*	9	8	7	7	7	6	6	
MAR	*	11	10	9	8	8	7	7	
APR	*	13	12	11	10	9	9	8	
MAY	*	16	14	12	11	10	10	9	
JUN	*	17	15	13	12	11	10	9	
JUL	*	16	14	13	12	11	10	9	
AUG	*	14	13	11	11	10	9	8	
SEP	*	12	11	10	9	8	8	7	
OCT	*	10	9	8	7	7	7	6	
NOV	*	7	7	6	6	6	6	6	
DEC	*	6	6	6	5	5	5	5	

******* ORIENTATION=75 DEGREES OFF DUE SOUTH *******

INCLINATION=	*	0	15	30	45	60	75	90	DEGREES
JAN	*	7	6	5	5	5	4	4	
FEB	*	9	8	7	6	6	5	5	
MAR	*	11	10	9	8	7	7	6	
APR	*	13	12	10	9	9	8	7	
MAY	*	16	14	12	11	10	9	8	
JUN	*	17	15	13	12	11	10	9	
JUL	*	16	14	13	11	10	9	8	
AUG	*	14	12	11	10	9	8	8	
SEP	*	12	10	9	8	8	7	7	
OCT	*	10	8	7	7	6	6	5	
NOV	*	7	6	6	5	5	5	4	
DEC	*	6	5	5	5	4	4	4	

******* ORIENTATION=90 DEGREES OFF DUE SOUTH *******

INCLINATION=	*	0	15	30	45	60	75	90	DEGREES
JAN	*	7	5	5	4	4	3	3	
FEB	*	9	7	6	5	5	5	4	
MAR	*	11	9	8	7	6	6	5	
APR	*	13	12	10	9	8	7	6	
MAY	*	16	14	12	10	9	8	8	
JUN	*	17	15	13	11	10	9	8	
JUL	*	16	14	12	11	10	9	8	
AUG	*	14	12	11	10	8	8	7	
SEP	*	12	10	9	8	7	6	6	
OCT	*	10	8	7	6	5	5	5	
NOV	*	7	6	5	4	4	4	3	
DEC	*	6	5	4	4	3	3	3	

Table A-49 FUEL CONVERSION FACTORS

FUEL TYPES	EQUIVALENT FUEL CONVERSION FACTORS Cf		FUEL CONVERSION EFFICIENCIES Ce
#2 Fuel Oil	48 825 W.h/gal	10 741 W.h/L	0.65
Liquid Propane	32 326 W.h/gal	7 111 W.h/L	0.70
Natural Gas	293 W.h/ft^3	10 350 W.h/m^3	0.70
Electricity		1 000 W.h/kW.h	1.00

Notes: W = watt gal = imperial gallon h = hour
kW = kilowatt L = litre ft^3 = cubic foot m^3 = cubic metre

TABLE A-50 MEAN MONTHLY BRIGHT SUNSHINE HOURS FOR SELECTED LOCATIONS IN CANADA

	VANCOUVER B.C.	EDMONTON ALTA.	LETHBRIDGE ALTA.	SWIFT CURRENT SASK.	WINNIPEG MAN.	CHURCHILL MAN.	TORONTO ONT.	OTTAWA ONT.	MONTREAL QUE.	FREDERICTON N.B.	MONCTON N.B.	HALIFAX N.S.	CHARLOTTETOWN P.E.I.	ST. JOHN'S NFLD.
JAN.	48	81	107	95	100	73	77	92	79	103	105	95	89	66
FEB.	80	117	129	120	130	117	106	116	102	118	123	113	111	80
MARCH	126	168	171	157	167	171	149	151	145	141	144	148	140	97
APRIL	168	219	206	206	204	182	184	185	167	160	162	152	156	101
MAY	226	253	220	259	245	155	223	228	203	201	207	200	212	166
JUNE	223	251	265	269	250	200	263	250	222	203	205	212	221	173
JULY	280	302	345	339	294	273	286	274	244	234	228	239	244	232
AUG.	254	268	301	294	263	236	256	249	223	218	219	219	236	181
SEPT.	178	188	215	198	178	92	201	177	170	166	159	169	177	151
OCT.	110	154	178	165	133	64	151	137	126	140	145	152	134	108
NOV.	53	97	114	108	84	36	84	78	69	85	92	89	78	58
DEC.	38	75	96	87	78	47	67	73	61	91	88	88	59	51

Preliminary Cost Estimate Data

CONTENTS

1. **Foundation**
   a) Concrete Posts
   b) Concrete Blocks
   c) Slab on grade
2. **Unglazed Surfaces**
   a) Walls
   b) Roof
3. **Glazed Surfaces**
   a) Single-glazed fibreglass reinforced plastic walls or roof.
   b) Operating thermal pane glass windows.
   c) Fixed thermal pane glass.
   c) Fixed thermal pane glass.
   d) Dougle-glazed fibreglass reinforced plastic walls or roof.
   e) Polycarbonate double sheet on walls or roof.
4. **Floor**
   a) Concrete pavers
   b) Wood floor
5. **Insulating curtains**
6. **Ventilation**
7. **Electrical**
8. **Doors**
9. **Heating**

Preliminary Cost Estimate Data

Solarium Element	Dimension	Installed Cost ($)		D.I.Y. Cost ($)	
		Unit Dimension		Unit Dimension	
		Metric	Imperial	Metric	Imperial
Foundation					
A.	Each	61.00	61.00	22.00	22.00
B.	Length of wall (m) (ft)	126.00	38.00	37.00	11.00
C.	Length of wall (m) (ft)	36.00	11.00	12.00	4.00
Unglazed Surfaces					
A.	Area of wall (m^2) (SF)	116.00	11.00	30.00	3.00
B.	Area of roof (m^2) (SF)	65.00	6.00	17.00	2.00
Glazed Surfaces					
A.	Area of wall or roof (m^2) (SF)	130.00	12.00	40.00	4.00
B.	Area of wall (m^2) (SF)	220.00	21.00	83.00	8.00
C.	Area of wall (m^2) (SF)	156.00	15.00	97.00	9.00
D.	Area of roof or wall (m^2) (SF)	153.00	14.00	57.00	5.00
E.	Area of roof (m^2) (SF)	155.00	15.00	88.00	8.00
Floor					
A.	Area of floor (m^2) (SF)	116.00	11.00	47.00	4.00
B.	Area of floor (m^2) (SF)	91.00	8.00	33.00	3.00
Insulating Curtains	Area of window (m^2) (SF)	103.00	10.00	75.00	7.00
Ventilation	Volume of room (m^2) (SF)	7.00	.20	5.00	.14
Electrical	Each Outlet	25.00	25.00	25.00	25.00
Doors	Each	200.00	200.00	140.00	140.00
Heating	Electric 1.5 kW baseboard heater with thermostat, and outlet	120.00		90.00	

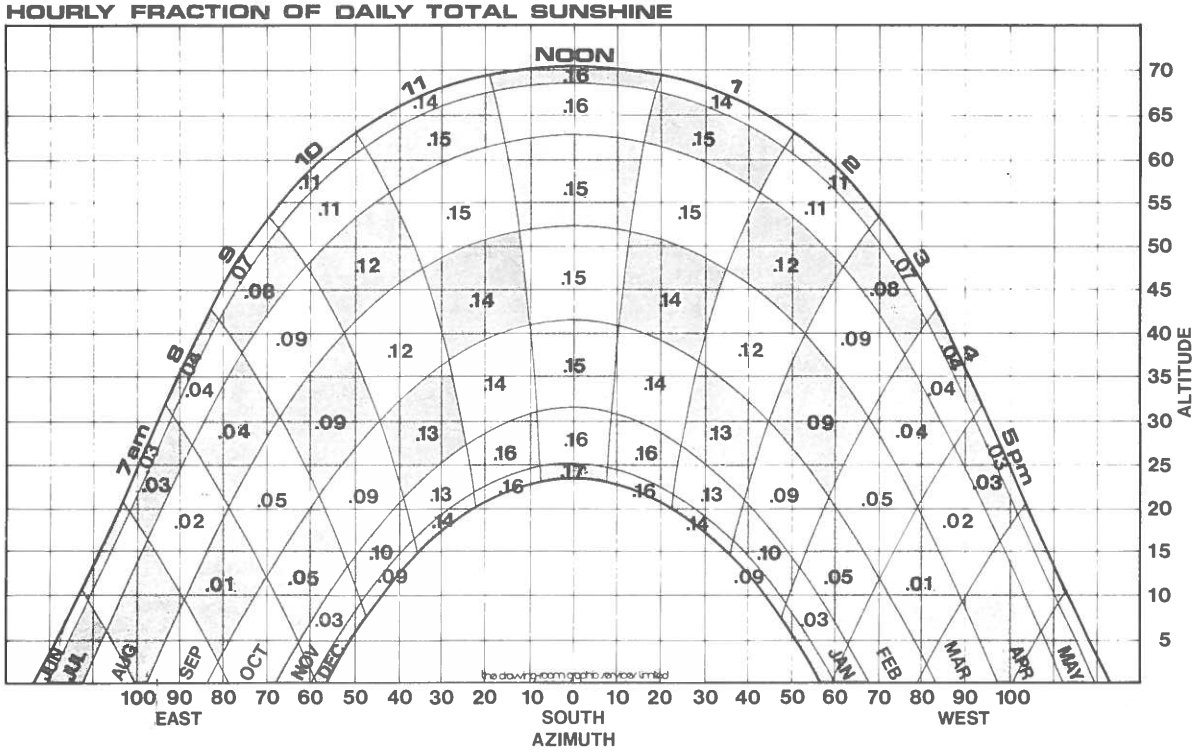
Preliminary Cost Estimate Data

DETAILED DESCRIPTION

1. Foundation
   a) **Concrete posts** shall be 200 mm in diameter, 1220 mm o.c. to a depth of 1370 mm and to the desired height.
   b) **Concrete blocks** — 200 × 200 × 400 mm. This price includes excavation, backfilling and footing. The depth of the wall shall be 1370 mm below grade and 200 mm above grade.
   c) **Slab on grade**. This price includes all formwork, reinforcing, RSI 1.76 type 2 rigid insulation, gravel and concrete.
2. Unglazed surfaces
   a) **Walls**: Includes 38 × 89 spruce studs at 600 mm o.c. RSI 1 friction fit insulation 0.15 mm vapour barrier, interior prefinished masonite panelling and exterior fir panelling.
   b) **Roof**: includes 38 × 140 spruce rafters at 600 mm o.c. RSI 6 insulation, 9.5 mm spruce sheating, No. 10 standard asphalt shingles, interior panelling and all flashings.
3. Glazed surfaces
   a) **Walls**: This price includes fiberglass reinforced plastic 38 × 89 mm spruce studs at 600 mm o.c. 19 × 89 mm spruce strapping, horizontally at 1200 mm o.c., and fiberglass reinforced plastic.
   Roof: This price includes fiberglass reinforced plastic 38 × 140 spruce rafters at 600 mm o.c. and 19 × 89 spruce strapping at 812 mm o.c..
   b) This price includes operating thermal glazed windows 1150 × 520 and the balance of the wall insulated and finished as in unglazed surfaces 2a) above.
   c) This price includes fixed thermal pane glass windows, all framing members and mouldings.
   d) Same as 3a) but with double-sheet of fiberglass reinforced plastic.
   e) **Roof**: This price includes a double skin polycarbonate sheet, 38 × 140 spruce rafters, 19 × 89 spruce strapping over the glazing system.
4. Floor
   a) **Concrete pavers**: This price includes interlocking concrete pavers over 100 mm of 16 mm crushed stone over 121.76 type 2 polyboard.
   b) **Wood Floor**: Includes 38 × 235 spruce floor joists at 400 mm o.c., RSI 4.9 friction fit insulation, 0.15 mm vapour barrier, 15.5 mm tongue and groove spruce sheathing over floor and 9.5 mm spruce sheating under floor.
5. Insulating Curtains:
   Shall be of the expanding silver coated mylar type.
6. Ventilation:
   Includes small fans, limited duct work and electrical work necessary for their installation.
7. Electrical:
   The price given is per outlet.
8. Doors:
   Are based on exterior grade doors, frame and all hardware.
9. Heating
   Is 1.5 kW electric baseboard with thermostat and baseboard.

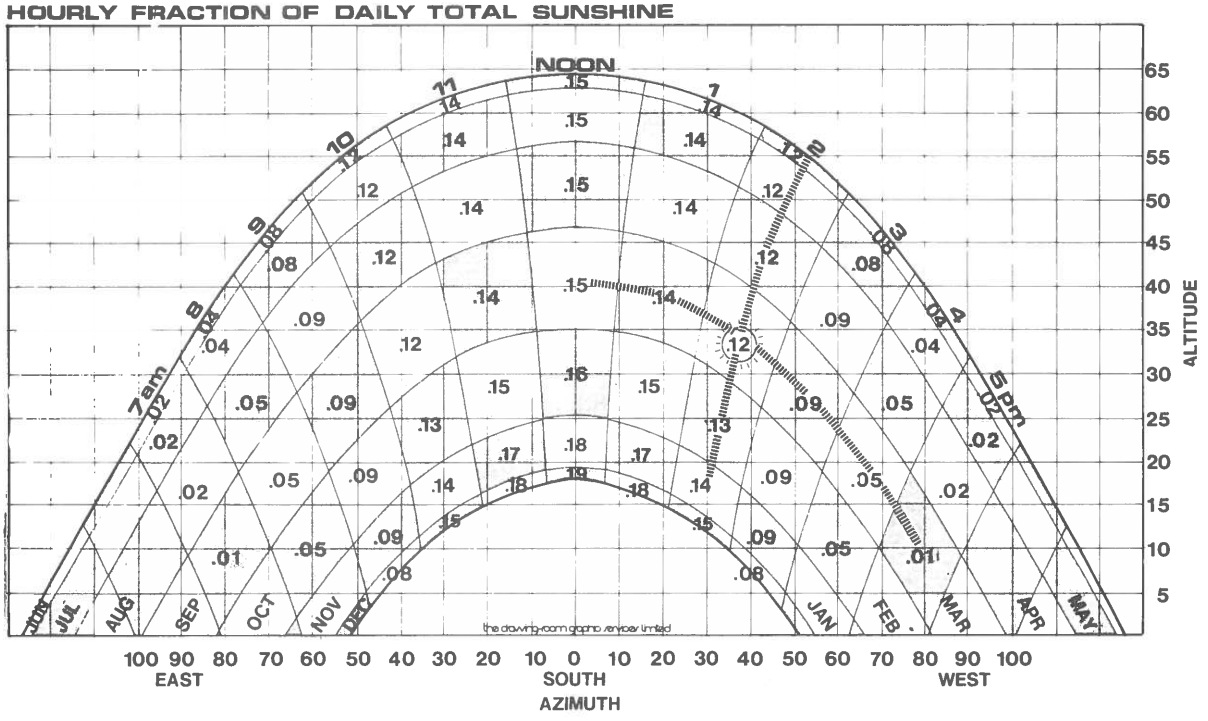
SUN PATH CHART 43° NORTH

HOURLY FRACTION OF DAILY TOTAL SUNSHINE



SUN PATH CHART 49° NORTH

HOURLY FRACTION OF DAILY TOTAL SUNSHINE



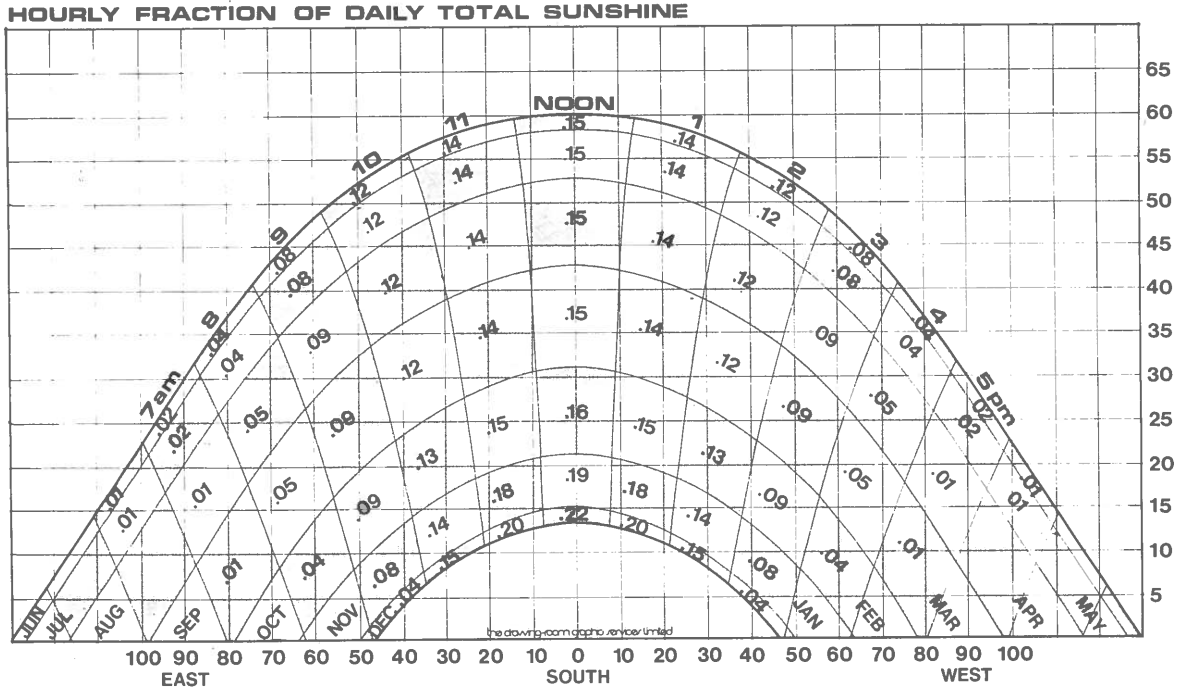
The sun path chart is a two dimensional record of the annual movements of the sun across the sky, for a specific latitude. The base line represents a flat horizon. The bottom arch is the path of the sun at the winter solstice (Dec.21), the top arch is the summer solstice (June 21). Note that the sun traces the same path twice a year, as the days get longer, and as they get shorter. (For example, September and March are paired on the chart). Months are centred on the 21st day of each month.

Radial lines indicate the time of day (standard time). Time numbers are centred on each 'square'.

The number in each square indicates the fraction of solar energy (under perfect conditions) which occurs during a one hour portion, between half hour before, and half hour after, the time indicated for the 21st day of the month. The example plotted shows that on March 21/Sept.21 12% of the daily total solar energy falling on a vertical surface will occur (under ideal conditions) between 1:30 p.m. and 2:30 p.m., local standard time.

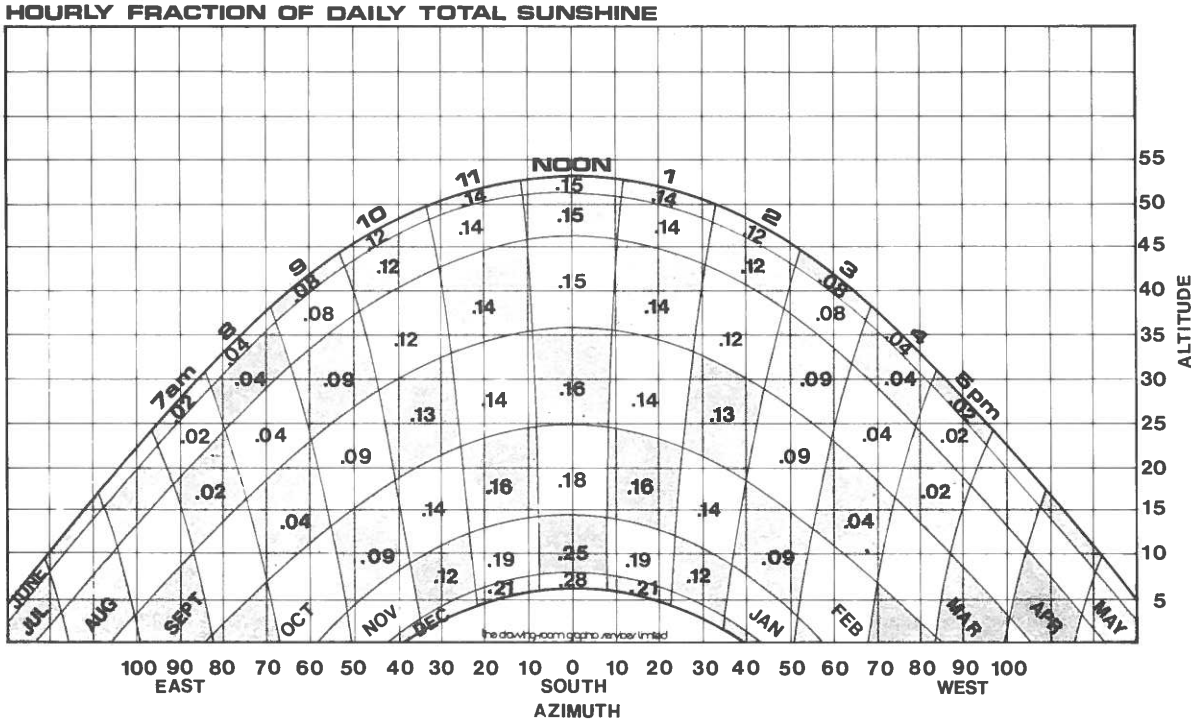
SUN PATH CHART 53° NORTH

HOURLY FRACTION OF DAILY TOTAL SUNSHINE



SUN PATH CHART 60° NORTH

HOURLY FRACTION OF DAILY TOTAL SUNSHINE



Discount Rate d%	Number of Years to Payment N					
	5	10	15	20	25	30
2	0.906	0.820	0.743	0.673	0.609	0.552
4	0.822	0.676	0.555	0.456	0.375	0.308
6	0.747	0.558	0.417	0.312	0.233	0.174
8	0.681	0.463	0.315	0.214	0.146	0.099
10	0.621	0.385	0.239	0.149	0.092	0.057
12	0.567	0.322	0.183	0.104	0.059	0.033
14	0.519	0.270	0.140	0.073	0.038	0.020
16	0.476	0.227	0.108	0.051	0.024	0.012
18	0.437	0.191	0.083	0.036	0.016	0.007

Table A-56: Single Payment Factor

N = 5

Discount Rate d%	Rate of Price Increase - Inflation or Escalation %									
	0	2	4	6	8	10	12	14	16	18
0	1.000	1.104	1.217	1.338	1.469	1.611	1.762	1.925	2.100	2.288
2	0.906	1.000	1.102	1.212	1.331	1.459	1.596	1.744	1.902	2.072
4	0.822	0.907	1.000	1.100	1.208	1.324	1.449	1.583	1.726	1.880
6	0.747	0.825	0.909	1.000	1.098	1.203	1.317	1.439	1.569	1.710
8	0.681	0.751	0.828	0.911	1.000	1.096	1.199	1.310	1.429	1.557
10	0.621	0.686	0.755	0.831	0.912	1.000	1.094	1.196	1.304	1.421
12	0.567	0.626	0.690	0.759	0.834	0.914	1.000	1.093	1.192	1.298
14	0.519	0.573	0.632	0.695	0.763	0.836	0.915	1.000	1.091	1.188
16	0.476	0.526	0.579	0.637	0.700	0.767	0.839	0.917	1.000	1.089
18	0.437	0.483	0.532	0.585	0.642	0.704	0.770	0.842	0.918	1.000

N = 10

Discount Rate d%	Rate of Price Increase - Inflation or Escalation %									
	0	2	4	6	8	10	12	14	16	18
0	1.000	1.219	1.480	1.791	2.159	2.594	3.106	3.707	4.411	5.234
2	0.820	1.000	1.214	1.469	1.771	2.128	2.548	3.041	3.619	4.294
4	0.676	0.824	1.000	1.210	1.458	1.752	2.098	2.504	2.980	3.536
6	0.558	0.681	0.827	1.000	1.206	1.448	1.734	2.070	2.463	2.923
8	0.463	0.565	0.686	0.830	1.000	1.201	1.439	1.717	2.043	2.424
10	0.386	0.470	0.571	0.690	0.832	1.000	1.197	1.429	1.701	2.018
12	0.322	0.392	0.477	0.577	0.695	0.835	1.000	1.194	1.420	1.685
14	0.270	0.329	0.399	0.483	0.582	0.700	0.838	1.000	1.190	1.412
16	0.227	0.276	0.336	0.406	0.489	0.588	0.704	0.840	1.000	1.186
18	0.191	0.233	0.283	0.342	0.412	0.496	0.593	0.708	0.843	1.000

N = 15

Discount Rate d%	Rate of Price Increase - Inflation or Escalation %									
	0	2	4	6	8	10	12	14	16	18
0	1.000	1.346	1.801	2.397	3.172	4.177	5.474	7.138	9.266	11.974
2	0.743	1.000	1.338	1.781	2.357	3.104	4.067	5.304	6.884	8.897
4	0.555	0.747	1.000	1.331	1.761	2.319	3.039	3.963	5.145	6.649
6	0.417	0.562	0.751	1.000	1.324	1.743	2.284	2.978	3.866	4.996
8	0.315	0.424	0.568	0.755	1.000	1.317	1.725	2.250	2.921	3.775
10	0.239	0.322	0.431	0.574	0.759	1.000	1.310	1.709	2.218	2.866
12	0.183	0.246	0.329	0.438	0.580	0.763	1.000	1.304	1.693	2.188
14	0.140	0.189	0.252	0.336	0.444	0.585	0.767	1.000	1.298	1.677
16	0.108	0.145	0.194	0.259	0.342	0.451	0.591	0.770	1.000	1.292
18	0.084	0.112	0.150	0.200	0.265	0.349	0.457	0.596	0.774	1.000

N = 20

Discount Rate d%	Rate of Price Increase - Inflation or Escalation %									
	0	2	4	6	8	10	12	14	16	18
0	1.000	1.486	2.191	3.207	4.661	6.727	9.646	13.743	19.461	27.393
2	0.673	1.000	1.475	2.158	3.137	4.527	6.492	9.249	13.097	18.435
4	0.456	0.678	1.000	1.464	2.127	3.070	4.402	6.272	8.882	12.502
6	0.312	0.463	0.683	1.000	1.453	2.098	3.008	4.285	6.068	8.541
8	0.215	0.319	0.470	0.688	1.000	1.443	2.070	2.949	4.175	5.877
10	0.149	0.221	0.326	0.477	0.693	1.000	1.434	2.043	2.893	4.072
12	0.104	0.154	0.227	0.332	0.483	0.697	1.000	1.425	2.017	2.840
14	0.073	0.108	0.159	0.233	0.339	0.490	0.702	1.000	1.416	1.993
16	0.051	0.076	0.113	0.165	0.240	0.346	0.496	0.706	1.000	1.408
18	0.037	0.054	0.080	0.117	0.170	0.246	0.352	0.502	0.710	1.000

N = 25

Discount Rate d%	Rate of Price Increase - Inflation or Escalation %									
	0	2	4	6	8	10	12	14	16	18
0	1.000	1.641	2.666	4.292	6.848	10.835	17.000	26.462	40.874	62.669
2	0.610	1.000	1.625	2.616	4.174	6.064	10.362	16.129	24.914	38.198
4	0.375	0.615	1.000	1.610	2.569	4.064	6.377	9.926	15.333	23.508
6	0.233	0.382	0.621	1.000	1.596	2.524	3.961	6.166	9.524	14.602
8	0.146	0.240	0.389	0.627	1.000	1.582	2.482	3.864	5.968	9.151
10	0.092	0.151	0.246	0.396	0.632	1.000	1.569	2.442	3.773	5.784
12	0.059	0.097	0.157	0.252	0.403	0.637	1.000	1.557	2.404	3.686
14	0.038	0.062	0.101	0.162	0.259	0.409	0.642	1.000	1.545	2.368
16	0.024	0.040	0.065	0.105	0.168	0.265	0.416	0.647	1.000	1.533
18	0.016	0.026	0.043	0.068	0.109	0.173	0.271	0.422	0.652	1.000

N = 30

Discount Rate d%	Rate of Price Increase - Inflation or Escalation %									
	0	2	4	6	8	10	12	14	16	18
0	1.000	1.811	3.243	5.743	10.063	17.449	29.960	50.950	85.850	143.371
2	0.552	1.000	1.791	3.171	5.555	9.633	16.540	28.128	47.395	79.151
4	0.308	0.558	1.000	1.771	3.103	5.380	9.237	15.709	26.469	44.204
6	0.174	0.315	0.565	1.000	1.752	3.038	5.216	8.871	14.947	24.962
8	0.099	0.180	0.322	0.571	1.000	1.734	2.977	5.063	8.532	14.248
10	0.057	0.104	0.186	0.329	0.577	1.000	1.717	2.920	4.920	8.216
12	0.033	0.060	0.108	0.192	0.336	0.582	1.000	1.701	2.865	2.785
14	0.020	0.036	0.064	0.113	0.198	0.342	0.588	1.000	1.685	2.814
16	0.012	0.021	0.038	0.067	0.117	0.203	0.349	0.593	1.000	1.670
18	0.007	0.013	0.023	0.040	0.070	0.122	0.209	0.355	0.599	1.000

Discount Rate d%	Number of Years to Payment N					
	5	10	15	20	25	30
2	4.700	9.000	12.850	16.350	19.550	22.400
4	4.450	8.100	11.120	13.600	15.620	17.300
6	4.217	7.367	9.717	11.470	12.780	13.770
8	3.987	6.712	8.562	9.825	10.670	11.260
10	3.790	6.150	7.610	8.510	9.080	9.430
12	3.608	5.650	6.808	7.467	7.842	8.058
14	3.436	5.214	6.143	6.621	6.871	7.000
16	3.275	4.831	5.575	5.931	6.100	6.175
18	3.128	4.494	5.094	5.355	5.467	5.517

Table A-60: Multiple Payment Factor

N = 5

Discount Rate d%	Annual Inflation Rate i %, or Cost Escalation Rate e%									
	0	2	4	6	8	10	12	14	16	18
0	5.00	5.20	5.42	5.64	5.87	6.11	6.35	6.61	6.88	7.15
2	4.71	4.90	5.10	5.30	5.51	5.73	5.96	6.20	6.45	6.70
4	4.45	4.63	4.81	5.00	5.19	5.40	5.61	5.83	6.05	6.29
6	4.21	4.37	4.54	4.72	4.90	5.09	5.28	5.49	5.70	5.91
8	3.99	4.14	4.30	4.46	4.63	4.80	4.99	5.17	5.39	5.57
10	3.79	3.93	4.08	4.23	4.38	4.55	4.71	4.89	5.07	5.26
12	3.61	3.74	3.87	4.01	4.16	4.31	4.46	4.63	4.80	4.97
14	3.43	3.56	3.68	3.81	3.95	4.09	4.24	4.39	4.54	4.71
16	3.27	3.39	3.51	3.63	3.76	3.89	4.02	4.16	4.31	4.46
18	3.13	3.23	3.34	3.46	3.58	3.70	3.83	3.96	4.10	4.24

N = 10

Discount Rate d%	Annual Inflation Rate i %, or Cost Escalation Rate e%									
	0	2	4	6	8	10	12	14	16	18
0	10.00	10.95	12.01	13.18	14.49	15.94	17.55	19.34	21.32	23.52
2	8.98	9.80	10.72	11.73	12.85	14.10	15.48	17.01	18.71	20.59
4	8.11	8.83	9.62	10.49	11.46	12.54	13.73	15.05	16.50	18.11
6	7.36	7.98	8.67	9.43	10.28	11.21	12.24	13.38	14.66	16.02
8	6.71	7.26	7.86	8.53	9.26	10.07	10.97	11.95	13.04	14.24
10	6.15	6.63	7.16	7.74	8.38	9.09	9.88	10.73	11.68	12.72
12	5.65	6.08	6.54	7.06	7.62	8.24	8.93	9.68	10.51	11.42
14	5.22	5.59	6.01	6.46	6.96	7.51	8.11	8.77	9.50	10.30
16	4.83	5.17	5.54	5.94	6.38	6.87	7.40	7.98	8.62	9.32
18	4.49	4.79	5.12	5.48	5.88	6.31	6.78	7.29	7.97	8.48

N = 15

Discount Rate d%	Annual Inflation Rate i %, or Cost Escalation Rate e%									
	0	2	4	6	8	10	12	14	16	18
0	15.00	17.30	20.02	23.27	27.15	31.77	37.28	43.84	51.66	60.97
2	12.85	14.71	16.91	19.52	22.62	26.30	30.67	35.86	42.03	49.35
4	11.12	12.63	14.42	16.54	19.04	21.99	25.49	29.63	34.54	40.35
6	9.71	10.96	12.43	14.15	16.19	18.58	21.40	24.73	28.66	33.30
8	8.56	9.60	10.81	12.23	13.89	14.84	18.14	20.84	24.01	27.75
10	7.61	8.47	9.48	10.66	12.03	13.64	15.52	17.72	20.30	23.33
12	6.81	7.54	8.39	9.37	10.51	11.84	13.39	15.20	17.32	19.79
14	6.14	6.76	7.48	8.30	9.26	10.37	11.66	13.58	14.90	16.94
16	5.58	6.11	6.71	7.41	8.22	9.15	10.23	11.48	12.93	14.62
18	5.10	5.55	6.07	6.67	7.35	8.14	9.05	10.10	11.31	12.71

N = 20

Discount Rate d%	Annual Inflation Rate i %, or Cost Escalation Rate e%									
	0	2	4	6	8	10	12	14	16	18
0	20.00	24.30	29.78	36.79	45.76	57.28	72.05	91.03	115.38	146.63
2	16.35	19.61	23.73	28.96	35.61	44.09	54.92	68.74	86.40	108.97
4	13.59	16.09	19.23	23.19	28.18	34.51	42.53	52.72	65.68	82.16
6	11.47	13.42	15.84	18.87	22.67	27.44	33.46	41.07	50.68	62.84
8	9.82	11.35	13.25	15.60	18.52	22.17	26.74	32.48	39.69	48.77
10	8.51	9.74	11.24	13.08	15.36	18.18	21.69	26.07	31.55	38.40
12	7.47	8.46	9.66	11.13	12.92	15.13	17.86	21.24	25.44	30.66
14	6.62	7.43	8.41	9.58	11.01	12.76	14.91	17.54	20.80	24.83
16	5.93	5.60	7.40	8.35	9.51	10.91	12.61	14.69	17.24	20.38
18	5.35	5.91	6.57	7.36	8.30	9.43	10.80	12.46	14.48	16.95

Multiple Payment Factor with Escalation - MPFE

N = 25

Discount Rate d%	Annual Inflation Rate i %, or Cost Escalation Rate e%									
	0	2	4	6	8	10	12	14	16	18
0	25.00	32.03	41.65	54.86	73.11	98.35	133.33	181.87	249.21	342.60
2	19.52	24.51	31.25	40.40	52.91	70.05	93.62	126.08	170.82	232.49
4	15.62	19.23	24.04	30.50	39.22	51.07	67.21	99.26	119.44	160.77
6	12.78	15.44	18.94	23.59	29.78	38.11	49.35	64.57	85.24	113.35
8	10.68	12.67	15.27	18.67	23.15	29.10	37.06	47.73	62.11	81.51
10	9.08	10.61	12.57	15.10	18.40	22.73	28.45	36.06	46.21	59.80
12	7.84	9.04	10.54	12.46	14.93	18.13	22.32	27.83	35.11	44.77
14	6.87	7.82	8.99	10.47	12.35	14.76	17.88	21.93	27.23	34.21
16	6.10	6.86	7.79	8.95	10.41	12.25	14.60	17.63	21.55	26.66
18	5.47	6.09	6.84	7.76	8.91	10.34	12.15	14.44	17.39	21.19

N = 30

Discount Rate d%	Annual Inflation Rate i %, or Cost Escalation Rate e%									
	0	2	4	6	8	10	12	14	16	18
0	30.00	40.57	56.09	79.06	113.28	164.49	241.33	356.79	530.31	790.95
2	22.40	29.41	39.53	54.27	75.92	107.92	155.40	226.07	345.68	488.44
4	17.29	22.08	28.85	38.54	52.56	73.00	102.97	147.09	212.24	308.60
6	13.77	17.12	21.77	28.30	37.60	50.95	70.27	98.39	139.47	199.69
8	11.26	13.67	16.94	21.46	27.78	36.70	49.43	67.72	94.14	132.48
10	9.43	11.20	13.57	16.77	21.17	27.27	35.85	48.00	65.33	90.21
12	8.06	9.40	11.15	13.47	16.60	20.88	26.79	35.03	46.64	63.09
14	7.00	8.04	9.36	11.09	13.38	16.44	20.60	26.32	34.25	45.35
16	6.18	6.99	8.02	9.33	11.04	13.28	16.28	20.33	25.86	33.50
18	5.52	6.17	6.98	8.00	9.30	10.98	13.18	16.12	20.06	25.42

TABLE A-64 USEFUL CONVERSION FACTORS

	To Convert From	To	Multiply By
Length	foot (ft)	Metre (m)	0.3048
Area	square foot (ft^2)	Square metre (m^2)	0.0929
Volume	cubic foot (ft^3)	cubic metre (m^3)	0.0283
Volume	imperial gallon (gal)	liter (L)	4.5459
Energy	Btu	watt hour (W.h)	0.2931
Energy	Watt hour (W.h)	Joule (J)	3600.0
Solar flux	Btu per hour per square foot ($Btu/h.ft^2$)	watt per square metre (W/m^2)	3.1546
Solar flux	Langley per hour (Iangley/h)	watt per square metre (W/m^2)	11.628
U value	Btu per hour per square foot per degree Farenheit ($Btu/h.ft^2.^oF$)	watt per square metre per degree Celsius ($W/m^2.^oC$)	5.6782
R value	hour square foot degree Farenheit per Btu ($h.ft^2.^oF/Btu$)	square metre degree Celsius per watt ($m^2.^oC/W$)	0.1761
UA value	Btu per hour per degree Farenheit ($Btu/h.^oF$)	watt per degree Celsius ($W/^oC$)	0.5275
Energy	Kilowatt hour (kW.h)	watt hour (W.h)	1000.0
Pressure	inches of water (in H_20)	pascals (Pa)	249.08

Temperature Conversion: $^oF = (1.8 \times {}^oC) + 32$

$^oC = ({}^oF - 32)/1.8$

W1 General Specifications

Three-dimensional sketch of preliminary solarium design - Use extra sheets as required.

Volume of Solarium = area of cross section × length of solarium = _____ × _____ = _____ m^3

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8
Elements of the Solarium Envelope	Construction of Each Element	Surface Area *A* (m^2)	Heat Transfer Coefficient *U* ($W/m^2 \cdot °C$) (A-1 to A-11)	Glazing Factor *gf*	Orientation (Degrees from due south)	Inclination (glazing only) (degrees from horizontal)	Transmittance of Solar Radiation *tr* (A-12, A-13)

W1 General Specifications

W2 Calculation of the Average Daily Solar Heat Gain, Q, for Each Month

W3 Calculation of the Heat Loss Coefficient for the Solarium

Elements of the Solarium Envelope	While no insulating covers are being used to protect the glazing from heat loss (from W1 Col. 4) U (W/(m²·°C)) × (from W1 Col. 3) A (m²) = Col. 1 UA (W/°C)			While insulating covers are being used to protect the glazing from heat loss* (see text) $U_{combined}$ (W/(m²·°C)) × (from W1 Col. 3) A (m²) = Col. 2 UA (W/°C)		

Line 1	Sum of the UA values for all the elements of the solarium envelope.	Sub-Total		Sub-Total
Line 2	If the solarium floor has *not* been included in the list of elements above, then floor losses may be approximated by: Line 1 × 0.10 = × 0.10			Repeat the same figure for uninsulated floor losses
Line 3	Heat Loss Due to Air Infiltration (volume × 0.335 W/m³ · °C)			Repeat the same figure for air infiltration losses
Line 4	Overall heat loss coefficient for the Solarium (sum lines 1, 2 and 3)	*UA1*		Overall heat loss coefficient *UA2*

*If the solarium is to have insulating curtains, it is necessary to calculate two overall *UA* values:
UA 1 while the insulating curtains are open, leaving the glazing exposed;
UA 2 while the insulating curtains are closed, protecting the glazing from heat loss.
*Note that the value of *U* will remain unchanged from the value establisned in W1 for the non-glazed elements, or for glazed elements without insulating covers.

W4 Calculation of the Average Daily Heat Loss, L, from the Solarium for Each Month

	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6
	Average Inside Operating Temperature t_i (°C)	Average Outside Ambient Temperature t_o (°C)	Losses While Solarium is Operating During Hours of Daylight (from W3 Line 4)(see A-43 to A-48) $(t_i - t_o)$ (°C)	× $UA1$ (kW/°C)	× Duration (h/d)	= Losses (kW·h/d)
January						
February						
March						
April						
May						
June						
July						
August						
September						
October						
November						
December						

W4 Calculation of the Average Daily Heat Loss, L, from the Solarium for Each Month

	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11
	Losses While Solarium is Operating During Hours of Darkness				Total Average Daily Heat Losses (Col. 6 + Col 10) L (kW·h/d)
	(Repeat Col. 3) $(ti - to)$ (°C) ×	$UA2$ (kW/°C) ×	Duration (h/d) =	Losses (kW·h/d)	
January					
February					
March					
April					
May					
June					
July					
August					
September					
October					
November					
December					

W5 Calculation of the Net Monthly Heat Gain, H, and Equivalent Fuel Units, F, Produced Monthly

	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8
	Q (kW·h/d) (from W2 Col. 4)	L (kW·h/d) (from W4 Col. 11)	$Q - L$ (kW·h/d)	n (d)	H (kW·h)	Cf (kW·h/L) (see A-49)	Ce (see A-49)	F (L)
January				31				
February				28				
March				31				
April				30				
May				31				
June				30				
July				31				
August				31				
September				30				
October				31				
November				30				
December				31				

W6 Calculation of the Net Equivalent Fuel Saving, S, and Dollar Value, V, During the First Year of Operation

	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5
	Average Monthly Fuel Requirement for Space Heating (personal records) *M* in [ ] (inscribe units)	Equivalent Fuel Units Produced Monthly by the Solarium (from W5 Col. 10) *F* in [ ] (inscribe units)	Net Equivalent Monthly Fuel Saving *Sm* in [ ] (inscribe units)	Estimated Unit Cost of Fuel During the First Year of Operation ($/unit)	Dollar Value of *Sm:* *Vm* $
January					
February					
March					
April					
May					
June					
July					
August					
September					
October					
November					
December					

Box 1 S = [ ] The Total Annual Net Equivalent Fuel Saving

Box 2 V = [$] Total Dollar Value of the Net Equivalent Fuel Saving

W7 Calculation of the Operating Cost of the Solarium in the First Year of Operation

Col. 1 Description of Equipment	Col. 2 Equipment Power Rating (1 hp = 0.7457 kW) (1000 W = 1 kW)	Col. 3 Operating Time per Year (h)	Col. 4 Electrical Power Requirement (Col. 2 × Col. 3)	Col. 5 Operating Cost (Col.4 × $/kWh)
			Total	

W8 Preliminary Estimate of Construction Cost

Solarium Element	Description and Notes	Quantity	Unit Cost ($) see (A-53 to A-55)	Total Cost ($)
Demolition				
Foundations				
Exterior Walls (not glazed)				
Roof (not glazed)				
Floor				
Interior Partitions				
Doors				
Standard Windows				
Glazing and Glazing Frames				
Insulating Curtains				
Ventilation and Heat Distribution				
Heating				
Electrical				
Plumbing				
			Sub-Total	
			Add 15% of sub-total for miscellaneous	
			Total	
For do-it-yourself construction, the contingency can be reduced or even eliminated			Add 25% of total for contingencies	
			Estimated Cost	

W9 Life-Cycle Cost Analysis

Economic Parameters

Line 1 General Inflation Rate (% per annum) _____ i = _____

Line 2 Escalation Rate of the Cost of Non-Solar Energy: oil, gas, electricity (% per annum) _____ e = _____

Line 3 Discount Rate on Investments (% per annum) _____ d = _____

Line 4 Mortgage Interest Rate (% per annum) _____ i = _____

Term of the Mortgage (years) _____ t = _____

Line 5 Life-Cycle Period (years) _____ N = _____

Life-Cycle Expenses (*LCE*)

Cost Factor	Type of Expenses ($)		Present Value Multiplier	Present Value ($)
	Fixed Amount	First Year Payments		
Initial Cost				
Operating Cost				
Maintenance Repairs and Insurance				
Property Tax				
			LCE Total	$

Life-Cycle Benefits (*LCB*)

Saving Factor	Type of Benefits ($)		Present Value Multiplier	Present Value ($)
	Fixed Amount	First Year Benefits		
Fuel Savings				
Resale Value				
			LCB Total	$

Present Value of Life-Cycle Solar Savings (*LCSS*)

LCSS = *LCB* − *LCE* = $_____ − $_____ = $

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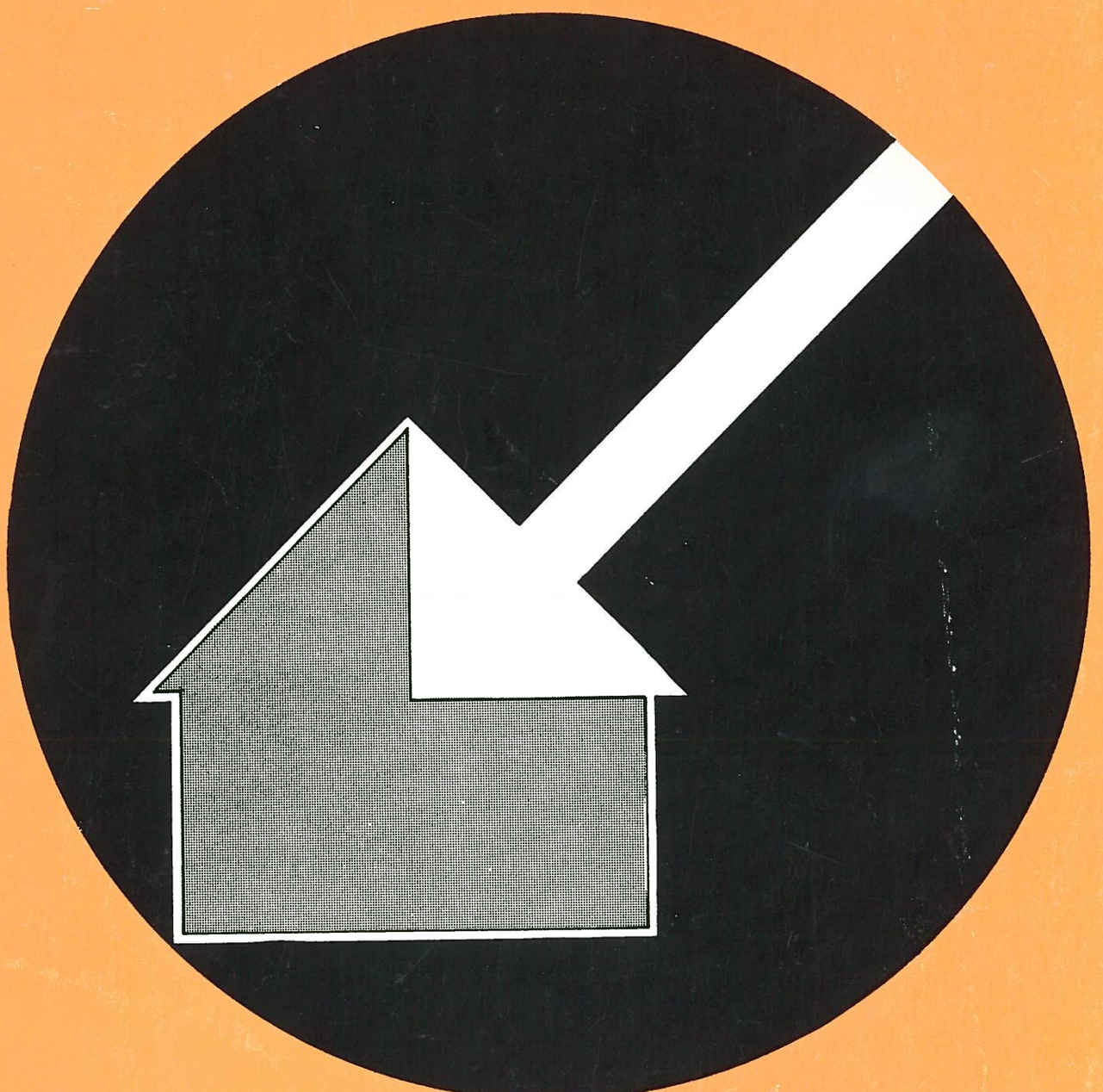
Organizations

The organization which has undertaken to encourage the use of solar energy in Canada is:

Solar Energy Society of Canada Incorporated
608 - 870 Cambridge Street
Winnipeg, Manitoba
Canada R3M 3H5

National Research Council of Canada

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